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Data Reconfiguration Service Compiler: Communications Among Heterogeneous Computer Centers Using Remote Resource Sharing

E. F. Harslem, J. Heafner and T. D. Wisniewski

A Report prepared for

ADVANCED RESEARCH PROJECTS AGENCY

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SANTA MONICA, CA 90406

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PREFACE

This report describes an experimental service being developed in conjunction with the ARPANET for the Information Processing Techniques Office of ARPA. The work is an integral part of an overall program to explore the application of computer resources to defense-related requirements.

ARPANET is a network of computers located on the premises of approximately 20 ARPA contractors. There are plans to include several military installations. ARPANET addresses the problem of how to share heterogeneous computer resources, separated geographically, with widely varying languages and hardware. This study examines a computer program to conveniently translate one computer's messages to another, much in the same way that a translator aids communication between people speaking different languages.

This report delineates a part of the computer program, the compiler. This communication service reformats messages passing between dissimilar computers in such a way that the ARPANET appears to adapt the user's computer programs.

The report discusses both the compiler and its implementation. It is intended for specialists who want to maintain the compiler or to construct a similar service. The reader is assumed to be familiar with R-860-ARPA, *The Data Reconfiguration Service--An Experiment in Adaptable Process/Process Communication.* AD-737318

SUMMARY

This report describes the use, implementation, and maintenance procedures for the Data Reconfiguration Service (DRS) Compiler. The nature, scope, and goals of the DRS experiment are also explained. ARPANET resources are rapidly expanding, and the number of users is increasing. Of growing concern is the problem of incompatibilities between the remote user's program or terminal and the service that the user wishes to access. The DRS experiment tests and evaluates one method of resolving different communication interfaces by placing the DRS between user and server to reconfigure the data they pass to each other.

Several ARPANET sites will provide the DRS to compare and contrast its operation with the current kind of operation, which specifies standard data representations to which both user and server must conform. A goal of the experiment is to ascertain if such ARPANET "adaptability" yields a valuable mode of operation for a large spectrum of users.

The report provides an overview of the language in which data-reconfiguration definitions are expressed. Syntax is stated in a formal notation.

Another overview describes the DRS interpreter as a component of the service that performs the actual data transformations in real time. The report provides a functional description of the interpreter, and briefly describes each instruction's operation.

The study highlights the compiler's functions and operations. The compiler processes descriptions of data reconfigurations (for use by the interpreter) as instructions for reformatting the data passing between user and server. The compile process entails a lexical scan of the reconfiguration definition, a syntactic verification of the resulting lexical units, and the generation of instructions for the interpreter. The compiler does not communicate directly with the person who creates the descriptions; instead, it operates through a file system to retrieve the descriptions and emit the instruction sequence.

Because this report is a guide to maintaining the compiler, one section describes the function of each subroutine, the use of the

compiler generator, and the use and format of data structures; it also shows how to modify semantic subroutines.

Emphasis was placed on expediting compiler implementation instead of producing a fast compiler or highly efficient instructions for the interpreter. Thus, suggested improvements are included. The improvements would reflect lower maintenance, more optimized generated instructions, and smaller memory requirements for the compiler. The report also details compiler implementation, and points out pitfalls and alternate strategies.

ACKNOWLEDGMENTS

The authors would like to thank Vinton Cerf, University of California at Los Angeles, for specifying an initial interpreter, and also for his comments on this report. The authors would also like to thank the following persons for their suggestions and review of this study: R. M. Balzer, R. L. Bisbey, The Rand Corporation; and James White, University of California at Santa Barbara.

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FIGURES

I. INTRODUCTION

THE NATURE OF THE EXPERIMENT

The ARPANET [1-5] embodies a growing number of service centers that provide a collection of unique and valuable services as resources to an expanding remote user group. Users are frequently located either at sites with minimal computational power or at sites remote from the service they need. Collectively, they use a varied set of peripheral devices and application programs. The services, on the other hand, are generally predecessors of the ARPANET; they accommodate a more limited set of devices and program interfaces than those presented by ARPANET users. ARPANET personnel are investigating the problem of identifying and applying techniques to aid user and service communications.

Three approaches to solving these disparate communications requirements immediately come to mind:

1. Servers can tailor their software interfaces for coupling to a much larger set of users.
2. Each user can provide the necessary software interfaces to all services he wishes to access.
3. High-level data-representation protocols, to which both users and servers conform, can be defined.

The first approach is highly unattractive because of the burden and responsibilities it places on service centers. The second is likewise undesirable because it implies upgrading user equipment and modifying user programs to meet service center specifications. The inclination to date has been toward the third approach. Thus far, standards have been specified for logical message-path management and teletype-like character transmissions. At higher linguistic levels (e.g., data and file transmission, remote job entry, and interactive graphics), protocols have not been defined, partly because of the divergence of user needs at these problem-oriented levels.

An interim (and perhaps even long-term) solution to this communications dichotomy is the use of a fourth approach--the Data Reconfiguration Service (DRS) [6-7]. The DRS is a computer program, transparent to both

user and server, that couples user and server and carries out transformations on data passing between them (see Fig. 1).

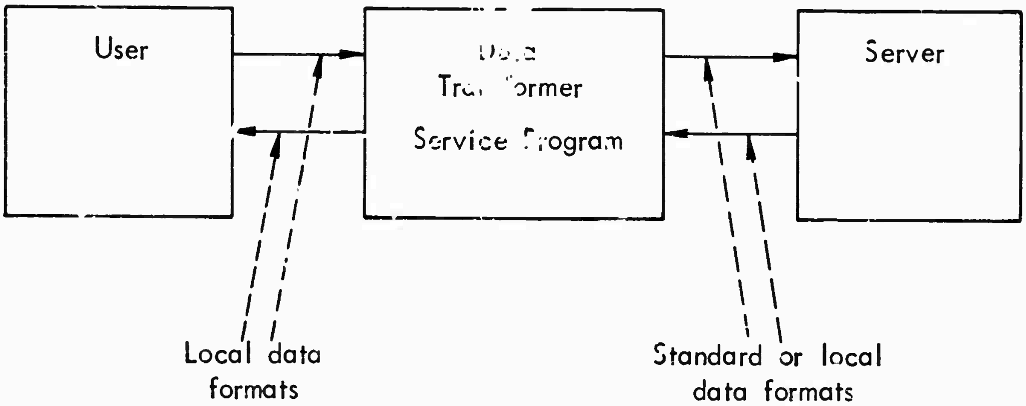

Fig. 1--Data "Transformer"

This approach offers several advantages. Because the reconfiguration definitions (called forms) are easily specified, user/server interface connections can be readily accomplished, with only minor changes made to their respective programs. For the $n \times m$ possible transformations (n users times m services), there need only be a single *adaptable* transformer in the ARPANET.

THE SCOPE OF THE EXPERIMENT

Four ARPANET sites (Rand, UCSB, UCLA, and MIT) are participating in DRS development. Specifically, Rand and UCLA are implementing DRS compilers. This report details the Rand implementation of the compiler. UCSB, UCLA, and MIT are implementing interpreters. The compilers take character-string definitions of data transformations and produce an intermediate (compiled) representation of the definition. The interpreters apply the compiled definitions to data streams passing between user and server in real time.

The Rand-implemented compiler and the UCSB interpreter will operate on UCSB's IBM 360/75 as a DRS service. The UCLA compiler and interpreter will operate on the UCLA Sigma-7. The MIT interpreter will offer the

reconfiguration service on a PDP-10, using data definitions compiled at UCLA and UCSB.

The DRS experiment is limited in scope. It is not intended as an intermediary for all ARPANET information exchange. The kinds of transformations that can be expressed easily and concisely in the DRS language include: character-set conversions, insertion and deletion of message headers and trailors (e.g., identifiers and counters), transposition of fields, data-format conversions (e.g., binary to binary-coded-decimal), expansion and compression of repeated symbol strings, and stripping or appending terminal signals.

Two kinds of uses are planned for the DRS. One is to offer a limited service to minimally configured nodes to gain some practical user experience. Another is to duplicate (in parallel) one or more existing user-server ties for purposes of comparative evaluation. Statistics of interest include declaration times of DRS data-reconfiguration definitions compared to coding time for the existing conventional implementations, and real-time data-transmission comparisons of the two operating modes.

THE GOALS OF THE EXPERIMENT

One experimental goal is to determine the viability of a mode of operation where a broad class of users can readily correspond with standard services, with minimal perturbations to the user's programs. The experiment is clearly prohibitive with respect to bandwidth and data rate for either large-volume data handling or highly interactive dialogues.

If a technically and economically aesthetic DRS results from this experiment, it could be provided as a standard service by: (1) distributing its capability to each major ARPANET service center so that both the DRS and the desired service reside at the same site, or (2) implementing a DRS interpreter in microcode on a small computer, as a unique service.

As a computer program, the DRS is expected to perform well on one-time-only data reformatting, where the original data are in one or more

formats and where writing programs to reformat the data would be time-consuming. Several examples of needed data transformations exist today, where the target data are to reside on a trillion-bit store to be shared by many installations. Other appropriate applications center around conversational-mode programs with low response-time requirements (10 to 30 characters/sec).

II. THE DRS LANGUAGE[†]

HIGHLIGHTS OF LANGUAGE SEMANTICS

A *form* is an operational definition of data reformatting performed on data passing over a unidirectional,[‡] logical ARPANET message path. Forms are specified to the DRS, then compiled and stored by the DRS. The interpreter applies a compiled form to an input data stream from the user and emits a reconfigured output stream to the server, and vice versa.

A form is an ordered collection of rules (language statements) for explicating reconfiguration operations on data streams. *Rules* specify replacement, comparison, or assignment operations on local variables in the context of the form. Rules are subdivided into an assemblage of terms. Data-stream-related terms describe the attributes (replication, length, value, and data type) of a field in the input or output stream. Rules consist of two parts: terms that describe or set conditions on the input data, and terms that format data for emission in the output stream. Each term may optionally and conditionally specify a transfer of control to the beginning of another rule. Rules are processed sequentially in the absence of explicit transfer of control.

[†]Appendix A includes the syntax of the DRS grammar. See Refs. 6 and 7 for a detailed description of DRS semantics.

[‡]In general, ARPANET connections are duplex, and a separate form is required to specify transformations on data passing in each direction.

III. THE DRS INTERPRETER

INTERPRETER OVERVIEW

The interpreter applies a pre-compiled form to a real-time data stream to effect data transformations† (see Fig. 2). The compiler produces the instructions, label table, literals, and identifiers. The interpreter is a stack machine driven by a Polish postfix instruction sequence. It consists of an instruction decoder; instruction execution routines (called operators) for data fetching, storing, and conversions; an assemblage of state registers for control; and a run-time stack to house instruction operands (see Fig. 3).

Run-time-stack operands are used for arithmetic expression evaluation, concatenation, and comparison; they are also used as arguments to input and output instruction routines.

The Current Input Pointer addresses the next bit to be processed in the input stream. The Rule Input Pointer addresses the bit position of the input stream corresponding to the beginning of the current rule. Two input pointers are required: the Current Input Pointer moves along as each term is processed, but the Rule Input Pointer is not advanced unless the rule correctly describes the input. The Output Pointer addresses the next available bit position for inserting data in the output stream. The Instruction Counter points to the current instruction of the pre-compiled instruction sequence. The Binary Switch is a true-false indicator set by input call and compare instructions, and checked by test and branch instructions. See Appendix B for instruction descriptions and the instruction repertoire.

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†Private communication with James White, Computer Research Laboratory, University of California, Santa Barbara.

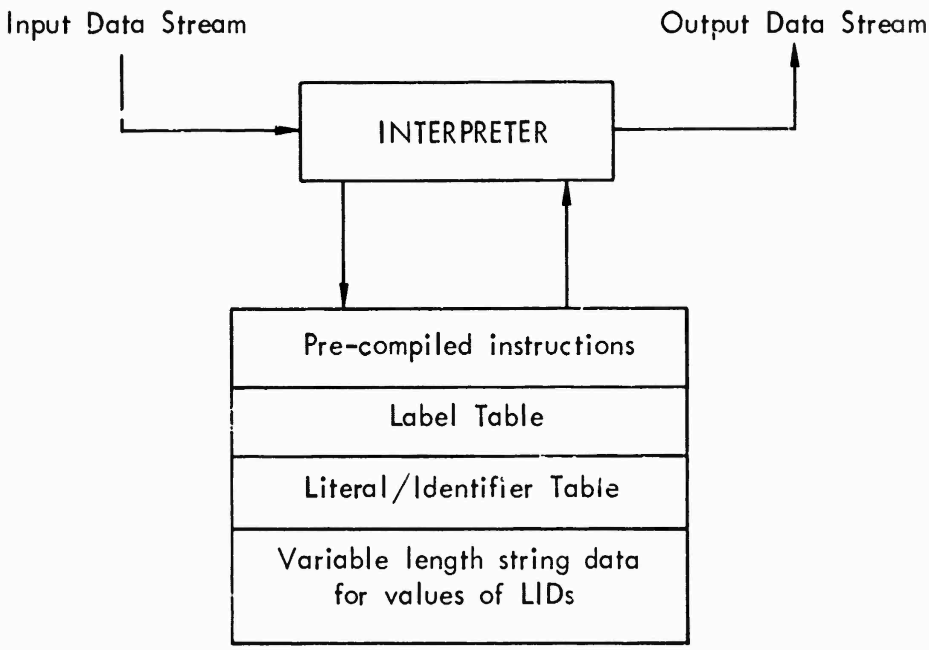

Fig. 2--Interpreter Interfaces

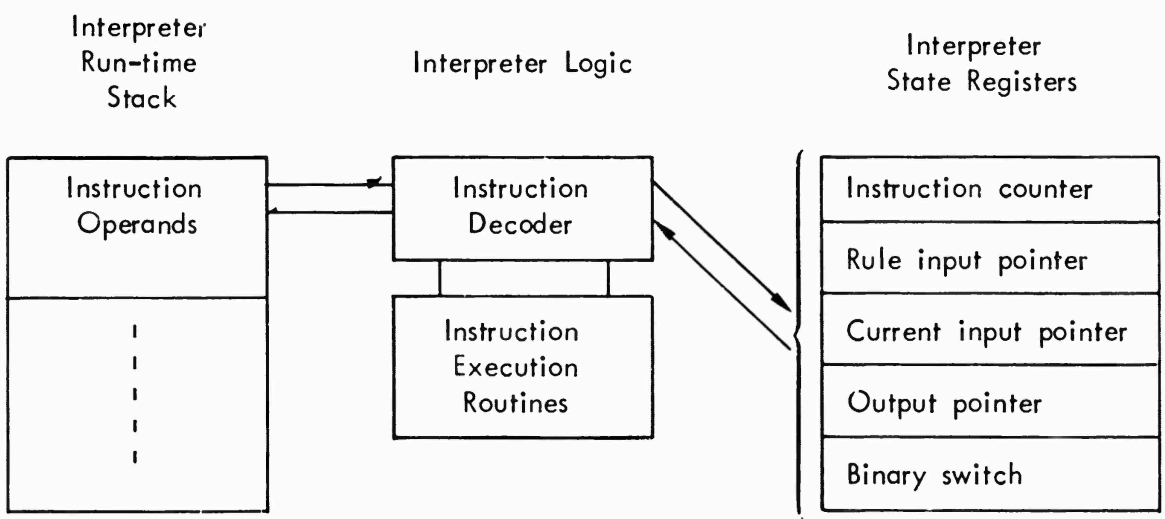

Fig. 3--Interpreter Components

IV. THE COMPILER

GLOSSARY

A *terminal* is any fundamental symbol string in the language, i.e., any string not defined in terms of other strings.

A *defined-type* is any symbol string in the language that is defined in terms of other symbol strings.

A *syntactic unit* is either a terminal or a defined-type.

The *Vocabulary Table* is a list of terminals.

A *production* is a statement in the syntactic specification of the language. Each production consists of a defined-type followed by a sequence of syntactic units.

COMPILER FUNCTIONAL OVERVIEW

The DRS compiler (a PL/1 program) accepts a *form* file as input and generates a source-diagnostic file for the user and two object files for execution by the interpreter. The compiler is logically made up of several data tables and three processes (the lexical analyzer, the syntax analyzer, and the semantic subroutines). The lexical-analyzer process scans and extracts meaningful characters, or groups of characters,† from the input stream (form definition). The character(s) is passed to the syntax-analyzer process to check the syntax of the input by comparing it to the syntactic units specified in a data table. If it agrees with any of the defined-types (see Appendix A), then the third process, a collection of semantic subroutines, is invoked to generate object code (see Fig. 4).

The data tables are pre-generated by a compiler generator, the LALR(k) Parser Generator,‡ developed by the Computer Research Group at the University of Toronto [8-9]. A Backus Normal Form (BNF) [10] representation of the DRS syntax is input to the Parser Generator.

---

†The characters correspond to primitive elements of the DRS syntax, e.g., delimiters, integers, and identifiers.

‡The Parser Generator was written to produce XPL-coded compilers. In this instance, the XPL was hand-translated to PL/1.

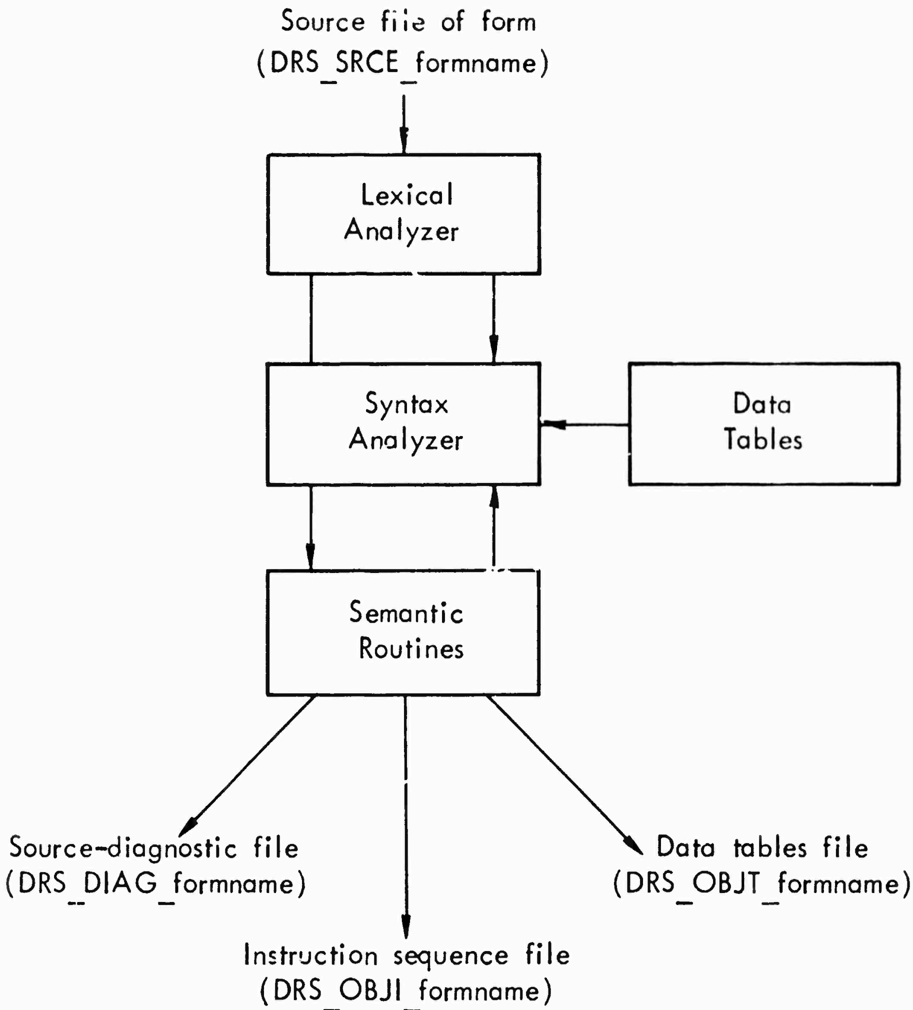

Fig. 4--Functional View of the Compiler

OVERVIEW OF COMPILER OPERATIONS

The compiler (see Appendix C) is invoked either as a job step or by being attached as an asychronous subtask. Its source *form* input and its diagnostic and object outputs use the facilities of the Simple Minded File System (SMFS) [11], a remote ARPANET resource at UCSB.

The name of the *form* to be compiled is passed on to the compiler either in the "PARM" field of the execute card† for the compiler job

†See IBM System Reference Library, Form No. C28-6539-9.

step or as a supervisor call parameter if the compiler is attached as a subtask. The compiler concatenates the parameter (*formname*) to the string 'DRS_SRCE_' to make up the complete file name of the source form, DRS_SRCE_formname. The formname is appended to similar strings to form the output file names shown in Fig. 4. The compiler creates and writes the three output files.

The diagnostic file is always written; it contains a copy of each source *rule*. If the rule parses correctly, the compiled code is listed after the rule in a format typical of an assembly listing. If the rule does not parse, a diagnostic, written after the source rule, replaces the compiled code. (See Appendix D for an example of the diagnostic file.) If the compilation is error-free, the instruction sequence and data-table files are also written; if syntax errors are detected, these object files are purged.

LEXICAL ANALYSIS

The DRS syntax contains a set of terminal symbols. The "arbitrary number of" symbol, #, denoting the replication factor, is a terminal. Delimiters, arithmetic and concatenate operators are also terminals. Integers, alphanumeric strings, and literals are also terminal or primitive in the sense that they are fundamentally irreducible, as opposed to an arithmetic expression that might be reducible to a series of binary operations.

The Parser Generator deduces terminals from the BNF language description, and generates them to make up the Vocabulary Table.

The lexical analyzer detects terminals as it processes the input stream (form definition). By ignoring non-terminals, the lexical analyzer filters out ARPANET control characters. Upon detection of a terminal, an index† (rather than the terminal itself) corresponding to the entry in the Vocabulary Table is returned to the syntax analyzer. A special terminal (goal symbol)‡ that cannot occur in the input stream

---

†The terminal type is available through the index, and the input terminal string is placed in a variable.

‡See the first production, GLUMP, in the syntax in Appendix A.

indicates the end of a form. The lexical analyzer translates an end-of-file from the form-definition source into the goal symbol, and passes the appropriate Vocabulary Table index to the syntax analyzer. (The goal symbol appears as "_|_" in the syntax specification.) Literals are stripped of their delimiting double quote marks before being passed to the syntax analyzer.

SYNTAX ANALYSIS

The syntax analyzer is a "state machine," driven by initialized state tables produced by the Parser Generator. The tables guide the syntax analysis, which in turn calls upon the lexical analyzer to supply terminals. In fact, the Parser Generator produces a variety of output (see Appendix A). For example, it indicates ambiguities in the syntax and whether or not they can be resolved by looking ahead one terminal in the input stream. The most important output (for the present discussion) is a symbolic deck of XPL [12] table declarations and initialization constants. The tables are used in syntax analysis, except for the Vocabulary Table, which is placed in the lexical analyzer because it contains the terminals of the DRS language.

Analysis involves moving from one state to another, where the next state is a function of the current state and, for some states, a function of the lexical input. Each state produces a specific set of actions, e.g., requesting input or generating (compiling) code. The kinds of states include *read*, *look-ahead*, *push-down*, and *apply*.

A *read state* gets the next terminal from the lexical analyzer (the current state is pushed down on a state stack). A set of acceptable terminals is associated with each read state. Each terminal in the set leads to a next state. If the terminal read matches one of those acceptable in the present state, a transition is made to the corresponding next state. Failure to match one of the state's set is indicated by a syntax error, whereupon the current rule is ignored by skipping past the semicolon delimiter; the parse process then continues with the next rule.

When the syntax analyzer is in a *look-ahead state*, it asks the lexical analyzer for a *copy* of the next terminal (without advancing the

lexical analyzer's pointer in the form input). That is, look-ahead leaves the terminal available for subsequent look-ahead inspection or read. As in a read state, each look-ahead state has an associated set of acceptable terminals with corresponding next states. Likewise, if a terminal is matched with a member of the set, a transition is made to the corresponding state; otherwise, a syntax error occurs and processing resumes with the next rule.

A *push-down state* puts a syntactic unit on the stack. The next state is a function of only the current state. Push-down is used for productions that have empty righthand sides.

An *apply state* recognizes a defined-type and thus invokes a semantic subroutine, which in turn generates code. The next state is determined from the current state and the state stack. If a semantic error is detected, the syntax analyzer skips to the next rule to continue processing.

SEMANTIC SUBROUTINES

The semantic subroutines† generate the diagnostic file, the instruction sequence file, and the associated Label Table and Literal/Identifier Table file (see Fig. 4). The latter two files are accumulated internally until a complete form is recognized. A "record" of the diagnostic file, written whenever a rule is recognized, contains the source rule statement followed by either a diagnostic message or a list of the compiled instructions.

Table entries‡ are made whenever literals or labels are encountered as identifiers. Labels are checked for uniqueness. Identifiers may have multiple references, with different values and data types for each reference. Literals are checked for uniqueness so that identical literals appear only once in the Literal/Identifier Table. (When multiple definition of a label occurs, the error is reported to the syntax analyzer.)

---

†In the program, the semantic subroutines are collectively named SMNTC.

‡The entries are made by the subroutines FINDID, FINDLT, and FINDLB.

The semantic subroutines generate code directly, without creating an intermediate parse tree. Because the grammar requires a look-ahead of one terminal, there is no need to try alternate productions until the successful one is found. Consequently, there is no need to back up over code generated from each unsuccessful "try." The semantic subroutines are given a parameter to indicate the recognized production. Thus, semantic actions are invoked for each recognized production--setting variables, making an entry in the Lable Table or Literal/Identifier Table, or generating an instruction sequence. If any code is generated when a semantic subroutine is executed, a common exit is taken to update a location counter for the instruction sequence.

Specific semantic actions that occur upon recognition of the productions are listed below (the descriptions do not include pre- and post-processing common to each production):

GLUMP ::= FORM

An unconditional return with a code of zero is generated both in the instruction sequence and on the diagnostic file. The number of bytes of instructions is recorded in a length field preceding the instruction sequence (the interpreter uses the length to determine storage requirements). The instruction-sequence file is written along with the length field. Similar length fields precede the Label Table and the Literal/Identifier Table, which are written as shown in Fig. 4. The Label Table and the Literal/Identifier Table are written as unformatted SMFS files.

FORM ::= RULE | FORM RULE

No action is taken.

RULE ::= LABEL INPUTSTREAM OUTPUTSTREAM;

Unless the separator ":" appears first, an input/output term-flag is set to identify the next term encountered as an input term. The number-of-rules counter is incremented and the number-of-terms (within a rule) counter is cleared. The end-of-rule pseudo-instruction is generated. A second-pass compile is made (at the end of each rule) to complete the address field of AD instructions. On first-pass, these instructions are flagged with the pattern,

2130_{16}. The instruction sequence generated for the current rule is recorded[†] in the diagnostic file. The SICP instruction is generated as part of the sequence for the next rule.

LABEL ::= INTEGER

The label is entered in the Label Table; if the label is already defined, an error flag is set. An SICP is generated as the first instruction of the rule.

LABEL ::= <EMPTY>

An SICP is generated as the first instruction of a rule.

INPUTSTREAM ::= <EMPTY> | TERMS

Upon recognition of all input terms, an input/output term-flag is set to identify the terms that follow as output terms.

TERMS ::= TERM | TERMS, TERM

The Path Table (see p. 26) is cleared. Each element of the table corresponds to a defined-type and contains the number of the recognized production of that type. Semantic subroutines use the table to determine the history of the parse. Array HOLD is initialized to zeros. Each element of the array preserves indices in the Label Table or the Literal/Identifier Table. The fourth element of the array indicates whether the terms are input or output. The term counter is incremented and an end of term instruction is generated.

TERM ::= IDENTIFIER DESCRIPTOR

The input/output term-flag is checked. If it is on, the identifier descriptor was written on the wrong side of the input/output term delimiter ':'; thus, no code is generated. If the term occurs on the left (input) side of a rule, the instruction sequence LD x followed by STO is generated. When executed, this sequence stores the value of the identifier retrieved by the input call.

[†]The subroutine SPOCODE writes the file output.

TERM ::= IDENTIFIER

The following instruction sequence is generated:

```
NULL
LD      x
LIT
LD      x
LIC
LD      x
LIL
```

where x is an index in the Literal/Identifier Table. This sequence stacks the input/output parameters for the interpreter. The input/output term-flag is examined to determine which of the instructions (OUT, IND) to generate.

TERM ::= DESCRIPTOR | COMPARATOR

No action is taken.

IDENTIFIEE ::= IDENTIFIER

A semantic subroutine (the one corresponding to the defined-type IDENTIFIER) previously stored the identifier in the Literal/Identifier Table. This subroutine saves an index to the identifier for use by higher-level semantic subroutines.

TERM ::= IDENTIFIER

The identifier is a terminal symbol. If not already recorded, it is stored in the Literal/Identifier Table. An index in the table is saved for later use.

DESCRIPTOR ::= REP | DATYPE | VALUE | LENGTH CONTROL

No action is taken.

COMPARATOR ::= COMPAREXPR CONTROL | ASSGNEXPR CONTROL

No action is taken.

COMPAREXPR ::= CONCAT CONNECTIVE CONCAT

No action is taken.

ASSGNEXPR ::= IDENTIFIER .<=. CONCATEXPR

The instructions LD x followed by STO

are generated to store the value of the righthand side of the assignment statement in the identifier on the lefthand side. The x is an index in the Literal/Identifier Table for the identifier.

REP ::= #

The ARB operand is generated.

REP ::= ARITHEXPR

If the alternate production recognized for the defined-typ PRIMARY is INTEGER, then the integer is saved for higher-level semantic subroutines; otherwise, no action is taken.

REP ::= <EMPTY>

The NULL instruction is generated.

DATYPE ::= B | O | X | E | A | ED | AD | SB | T(IDENTIFIER)

The allowable data types are as follows:

Type	Meaning	Code
--	Undefined	0
B	Binary	1
O	Octal	2
X	Hexadecimal	3
E	EBCDIC	4
A	Network ASCII[†]	5
ED	EBCDIC Decimal Number	6
AD	Network ASCII Decimal Number	7
SB	Signed Binary	8

For all but T(IDENTIFIER), the instruction IC x is generated, where x is one of the values 0 through 8. For T(IDENTIFIER), the instruction sequence LD x followed by LIT is generated, where x is an index in the Literal/Identifier Table.

VALUE ::= CONCAT

The index to the Literal/Identifier Table is saved.

VALUE ::= <EMPTY>

The NULL instruction is generated.

[†] Network ASCII is a standard 7-bit ASCII code right-justified in an 8-bit field, with a high-order bit equal to zero.

LENGTH ::= ARITH

The integer is saved if the arithmetic expression is an integer. The OUT instruction is generated if the term is an output term; otherwise, the following instruction sequence is generated:

INS	
AD	end of rule instruction number
BF	
LD	if an IDENTIFIER was specified
STO	

LENGTH ::= <EMPTY>

The NULL instruction is generated.

CONNECTIVE ::= .LE. | .LT. | .GT. | .GE. | .EQ. | .NE.

For the syntactic unit below (left column), the code (right column) is generated:

.LE.	CLE
.LT.	CLT
.GT.	CGT
.GE.	CGE
.EQ.	CEQ
.NE.	CNE

The sequence AD followed by BF is generated.

CONCAT ::= VAL

No action is taken.

CONCAT ::= CONCAT || VAL

The CON instruction is generated.

VAL ::= LITERAL

The instruction LD x is generated, where x is an index in the Literal/Identifier Table.

VAL ::= ARITH

No action is taken.

ARITH ::= PRIMARY

No action is taken.

ARITH ::= ARITH OPERATOR PRIMARY

The instruction corresponding to the arithmetic operator is generated:

+ ADD
- SUB
* MUL
/ DIV

PRIMARY ::= IDENTIFIER | L(IDENTIFIER) | V(IDENTIFIER)

The instruction LD x is generated, where x is an index in the Literal/Identifier Table. An LIL is generated for L(IDENTIFIER); an LIV is generated for V(IDENTIFIER).

INTEGER ::= terminal

The value of the integer is saved and the instruction IC x is generated, where x is the value of the integer.

OPERATOR ::= + | - | * | /

No action is taken.

LITERAL ::= LITYPE LITSTRING

The literal is stored in the Literal/Identifier Table.

LITYPE ::= B | O | X | E | A | ED | AD | SB

No action is taken.

CONTROL ::= | OPTIONS

No action is taken.

OPTIONS ::= SFUR (ARITH) | SFUR (ARITH), SFUR (ARITH)

If the test is SR, FR, or UR, the RET instruction is generated; otherwise, the sequence LUL followed by BU is generated.

SFUR ::= S | SR

The instructions AD x followed by BF are generated, where x is the address of the first instruction in the next rule.

SFUR ::= F | SF

The sequence AD x followed by BT is generated.

SFUR ::= U | UR

No action is taken.

INPUT AND OUTPUT TO THE SMFS

Most input and output requests to the SMFS [11] are centralized in the input/output subroutine SMFSIO. Commands to SMFS are formatted as unaligned bit strings. UCSB's PL/1-Network interface [13] expects data as aligned array elements: however, the DRS compiler constructs the file commands in PL/1 structures. Data representation and access incompatibilities are resolved in SMFSIO by the POINT routine, through dummy dope vectors.

The input/output subroutine validates file operations. The SMFS and the ARPANET report the completion of a file transaction by returning a completion code† and by echoing the file command. The code is passed‡ to the caller after receiving and checking the echo.

COMPILER CHARACTERISTICS

The compiler is a PL/1 program. Figure 5 shows the memory requirements for each module.

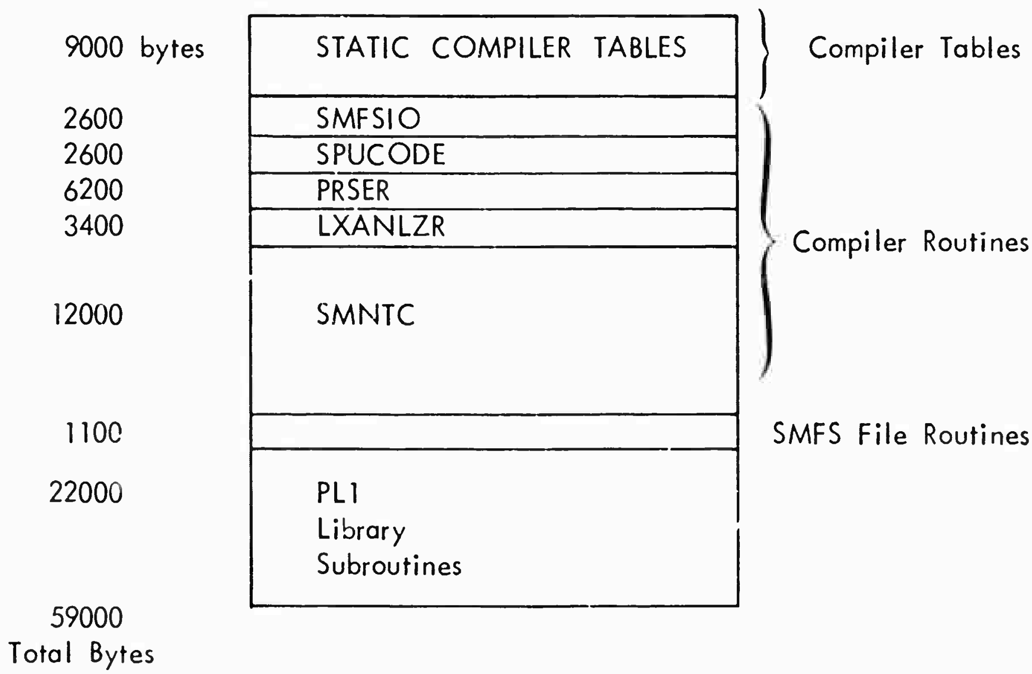

Fig. 5--Compiler Memory Requirements

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†The completion code is returned in parameter DS in SMFSIO.

‡The code is passed in the variable RSPONSE.

The program consists of compiler routines, tables, PL/1 library routines, and SMFS file-interface routines. The file-handling routines, written in assembler language, add little to the total size. The static tables account for approximately 15 percent of the program size; the remainder is compiler code and library routines. Within a 65K partition, the compiler uses about 6K for dynamic storage.

Because of the simple parse process and few explicit subroutine calls, the compiler is fast. At present, there are no statistics on the compile rate.

MAINTENANCE

Subroutines and the Source Language

The compiler consists of the following routines:

PRSER	The syntax analyzer.
LXANLZR	The lexical analyzer.
SMNTC	The semantic routines.
FINDLT	Routine to seek and insert literals.
FINDLB	Routine to seek and insert labels.
FINDID	Routine to seek and insert identifiers.
SMFSIO	Routine to input/output to the SMFS.
POINT	Routine to overlay arrays onto structures for input/output.

The indentations indicate nested subroutines. The first three subroutines are the major components of the compiler (see pp. 10-12). The three FIND subroutines are called exclusively by the semantic subroutines. SMFSIO uses the SMFS. The PRSER, LXANLZR, and SMNTC use SMFSIO, although PRSER also directs the file system to open and close files. Subroutine POINT converts data representations between the PL/1-Network interface [13] and the compiler.

PL/1 F-level compiler, version 5, was used. The PL/1 character string built-in functions are necessary for the lexical analyzer. Note, for example, that the VERIFY function is not present in all PL/1 versions.

Some installations have a default source margin other than the one assumed for the compiler source code. Columns 1-72 must be used. The assumed PL/1 options are

EBCDIC	LOAD
CHAR60	NODECK
NOMACRO	FLAGW
NOSOURCE2	STMT
NOMACDCK	SIZE = 0133854
COMP	LINECNT = 057
SOURCE	OPT = 01
ATR	SORMGIN = (001, 072)
XREF	NOEXTDIC
NOEXTREF	NEST
NOLIST	OPLIST

Parser Generator

The *User's Guide* [8] describes options provided by the Generator. Appendix A is a listing from the run that generated the DRS compiler tables. Briefly, the following are the rules for constructing the BNF input.

Such specifications as IDENTIFIEE ::= IDENTIFIER are written simply as IDENTIFIEE IDENTIFIER. Successive productions are given on subsequent cards if the defined-type has alternatives. For example

```
OPERATOR  ::=  + | - | * | /
```

is input as

```
OPERATOR +
         -
         *
         /
```

The defined-types are terminated by a /* image. Names of the defined-types can be any continuous sequence of alphabetic characters, or the name can be delimited by the symbols '<' and '>', which allow imbedded blanks. For example, one can write either SFURIDENT or <SFUR IDENT> as the name of a defined-type. The name <EMPTY> specifically defines the null type. Finally, any symbol that does not appear on the left of a production is considered a terminal. The symbols +, -, *, / exemplify this in the DRS grammar because they appear only as alternate

productions of the defined-type OPERATOR. Note that the message below must precede the list of declarations; it indicates that the tables are acceptable (after editing from XPL to PL/1) as declarations to the DRS compiler (see Appendix A).

****NOTE**** GRAMMAR IS LALR(1)

The table declarations in Appendix A are identical to the punched cards produced by the Generator. The comment cards may be discarded. The declarations are edited to PL/1 in the following order.

- o Replace the phrase LITERALLY 'integer' by INITIAL (integer).
- o Remove the STATE-NAME array variable. (It is not used by the compiler.)
- o In the remaining array-variable declarations, replace any references to the variable declared 'LITERALLY' by the equivalent integer value.
- o In the remaining array-variable declarations, replace the attributes BIT (8) by BIN (8).
- o To save space, entries other than those containing terminal symbols can be discarded from the array-variable VOCAB.
- o The array index in XPL starts at zero, and in PL/1 at one; thus the initial XPL value should be deleted.
- o Use the contents of the vocabulary array to initialize the character-string variable, VOCAB, in the lexical analyzer. The vocabulary-array declaration may then be discarded.
- o Place the remaining array declarations in routine PRSER.

The Data Tables

Three data structures contain the compiler's output for the interpreter. They are (1) the Instruction-Sequence Table, (2) the Label Table (to resolve label references), and (3) the Literal/Identifier Table (to resolve references to literals or identifiers). The Defined-Type Table and Path Table control the semantic actions of the subroutines. To conserve space, all arrays are declared static.

Instruction-Sequence Table

The Instruction-Sequence Table (see Fig. 6) contains the instruction sequence (see Appendix E) executed by the interpreter. It is

headed by a byte-count of the instruction-sequence length. Every instruction is 16 bits in length.

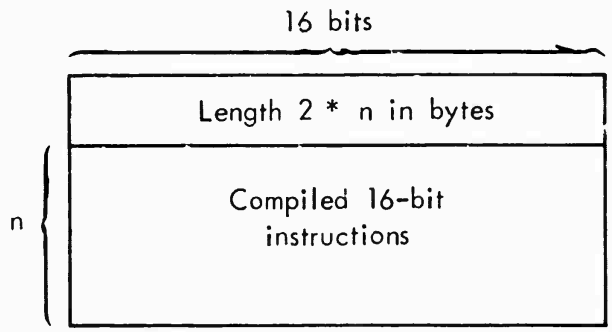


Fig. 6--Compiled Instruction Sequence File (DRS_OBJI_formname)

Label Table

The interpreter uses the Label Table (see Fig. 7) to resolve label references made by instructions. The table is headed by a byte count of the table's length. Each entry contains a label name (an integer n, $0 \leq n \leq 9999$) and a byte offset of the instruction in the instruction sequence.

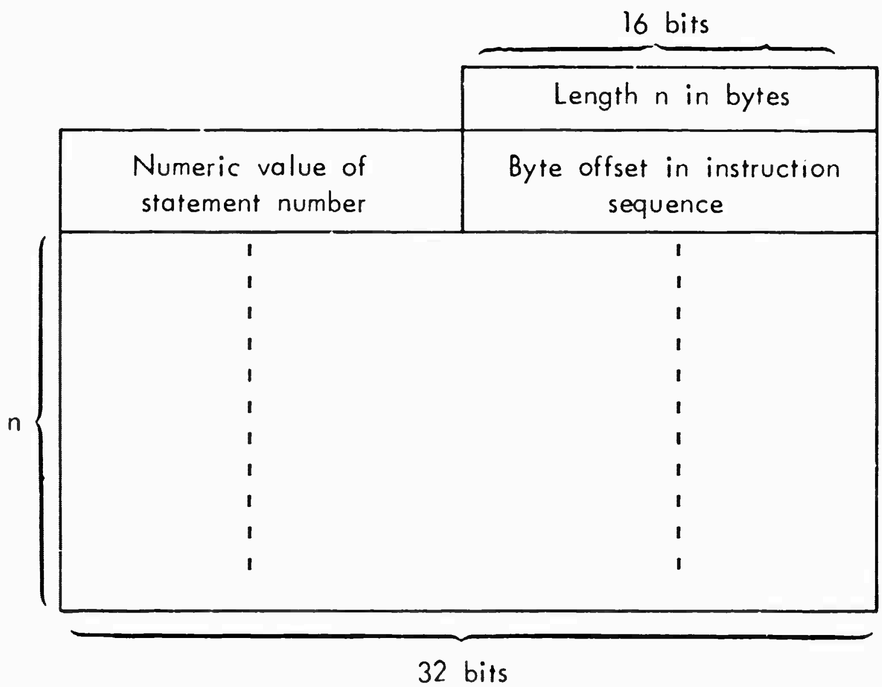
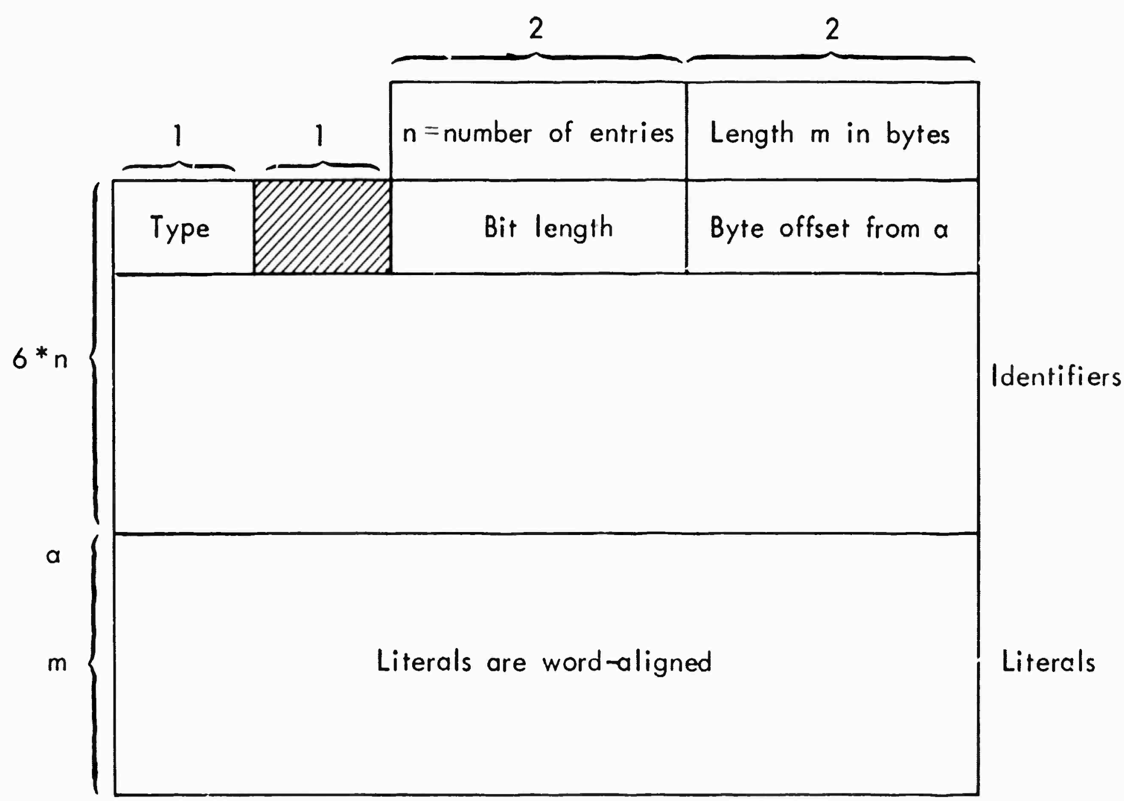


Fig. 7--Compiled Label Table: Part of File DRS_OBJT_formname

Literal/Identifier Table

Each literal and identifier encountered in the source is entered in the Literal/Identifier Table (see Fig. 8). Literals are fully described by their entries, because their attributes are known at compile time.



Legend:

Type 0 = undefined
1 = B (binary)
2 = Φ (octal)
3 = X (hexadecimal)
4 = E (EBCDIC)
5 = A (ASCII)
6 = ED (EBCDIC encoded decimal)
7 = AD (ASCII encoded decimal)
8 = SB (signed binary, two's complement)

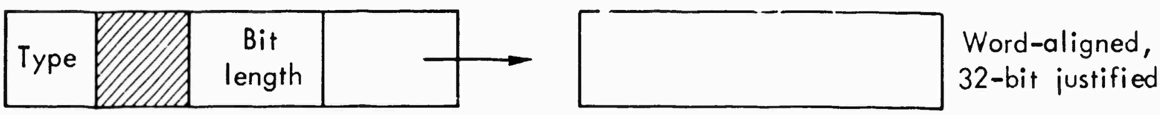
Fig. 8--Compiled Literals and Identifiers: Part of File DRS_OBJT_formname

The type field (Fig. 9) contains a value from zero to eight that identifies the literal as binary, octal, hexadecimal, etc. The bit length of the literal is stored in the second field (Fig. 9). The byte offset is the location of the literal value (relative to the start of the literal pool).

The second half of the table (Fig. 8) is a literal pool containing each literal value in the format that conforms to its type specification.

Identifiers have null entries in the Literal/Identifier Table. The entries with undefined type (zero values) are easily recognized by the interpreter as identifier entries. The length and offset fields are updated by the interpreter as it processes the input-data stream.

Types B, ϕ, X, AC, ED, and SB point to 32-bit word-aligned data as shown below.



Types E and A point to byte-aligned symbol streams as shown below.

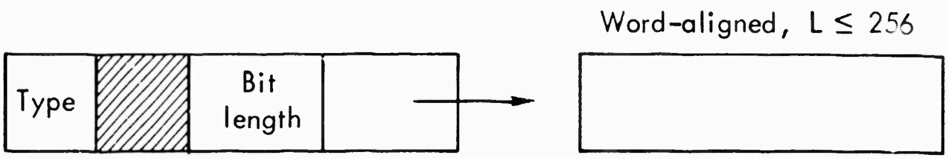


Fig. 9--Entries in the Literal/Identifier Table

<u>Defined-Type Table (DFTYPE)</u>

The Defined-Type Table, which is dependent on the syntax specification, records semantic actions. Each entry corresponds to a production in the DRS syntax, and has a non-zero value that is the ordinal of the defined-type for that production. For example, the specification for the defined-type FORM

FORM ::= RULE | FORM RULE

is currently the second defined-type in the DRS syntax. The production alternatives, RULE and FORM RULE, are the second and third productions in the specification. Thus, both the second and third entries in the Defined-Type Table have the value 2 because they are produced from the second defined-type, i.e., FORM.

A positive value indicates that a non-null semantic subroutine exists for the production. If the value is negative, the semantic subroutine is null. All productions are recognized, but only those with positive table values cause semantic actions.

Path Table (LTRNTKN)

The Path Table records the productions recognized while parsing a rule. Each entry corresponds to a defined-type. For example, if the third syntactic production is recognized, the second entry of the Path Table contains a 3 because the third production belongs to the second defined-type. The semantic subroutines use the table to determine the history of the parse. For example, there is a semantic subroutine for the second production of the defined-type

ARITH ::= PRIMARY | ARITH OPERATOR PRIMARY.

Recognition of the production requires that the terms ARITH, OPERATOR, and PRIMARY be previously recognized. (For each of these earlier recognitions, the semantic subroutines did generate instructions to load the run-time stack with the left and right parts of the arithmetic statement.) The term OPERATOR produces no semantic action, but the production of the defined-type OPERATOR is recorded in the Path Table. When the semantic subroutine for ARITH's second production is invoked, the table is examined to determine which OPERATOR production was previously recognized, and thus, which arithmetic instruction should be generated.

Modifying the Semantic Subroutines

Three modifications to the semantic subroutines, not involving syntax changes, are discussed below.† These are (1) changing a non-null

†Also see Appendix F.

subroutine, (2) inserting a non-null subroutine, and (3) making a non-null subroutine null. Null subroutines perform no semantic actions.

Modifying a Non-Null Subroutine

Each non-null subroutine is identified by a label of the form SROUT(x), where x corresponds to the production's BNF ordinal. When a production is recognized by the syntax analyzer (when it reaches an apply state), its ordinal is passed as an index to the semantic subroutines. SMNTC then transfers to the label subscripted by that index. For example, the grammar contains the following production:

LABEL ::= INTEGER | <EMPTY>

The Parser Generator assigns index numbers L_i and L_j to the productions INTEGER and <EMPTY>. If the first is recognized, the syntax analyzer passes L_i to the semantic subroutines, which determine whether the semantic subroutine is non-null. If not, SMNTC transfers to the label SROUT(L_i), to generate the code. Every non-null semantic subroutine terminates by transferring to EXIT, NOOP, or ERROR. To modify the existing semantic actions, replace the code bounded by the label and the transfer.

Replacing a Null by a Non-Null Semantic Subroutine

The semantic subroutines detect null subroutines by checking the Defined-Type Table entries. A negative entry means the subroutine is null, in which case the syntax analyzer regains control immediately after the production's number is recorded in the Path Table. To insert a non-null semantic subroutine for production L_i, change the L_i entry in the Defined-Type Table to the production's ordinal and insert the semantic code. The subscripted (SROUT(L_i)), precedes the code. The inserted code transfers to EXIT, NOOP, or ERROR. If the subroutine generates code, the subroutine transfers to EXIT to update the instruction counter. If no instructions are generated, the subroutine transfers to NOOP. If an error is detected, the subroutine goes to ERROR, where a return code is set for the syntax analyzer.

Deleting a Non-Null Subroutine

To make a non-null subroutine null, set a negative entry in the Defined-Type Table. Space can be saved either by converting the subroutine to comments or by deleting it.

Reflecting DRS Syntax Changes

When the DRS syntax is changed, the Defined-Type Table and the Path Table must be redefined to accommodate the new specification. In addition, semantic subroutines that are syntax dependent must be updated. To minimize program changes, place any new defined-types after the current defined-types. New table entries can be appended and the current semantic subroutines need not be changed. Redefine the maximum lengths of both tables to accommodate the new entries.

If a defined-type is changed, but the number of productions remains the same, replace the old type-definition by the new one. The tables do not change. Any other changes in syntax normally require redefining the tables and updating some semantic subroutines.

IMPROVEMENTS

The constraints of this experiment favored reducing compiler implementation time at the expense of optimization. That is, rather than concentrate on the efficiency of generated code to increase the interpreter's processing rate, we wanted feedback from early use to judge the effectiveness of this mode of operation.

This subsection identifies the more obvious compiler modifications. Compiler optimizing techniques have not been examined to produce the list of improvements. The kinds of improvements enumerated below entail both reorganization and recoding. Payoffs are reduced maintenance problems, more optimized code-generation, and reduced core requirements.

DRS Syntax

1. Reduce the number of productions to decrease program size. Some defined-types of the form shown below are extraneous.

A ::= B
B ::= C

Apply the transitive law that results in a production of the form shown below.

A ::= C

2. The syntax should be factored where possible, as illustrated below. Specify

X ::= B | C | D | E | F
Y ::= B | C | D | E | G

as

X ::= Z | F
Y ::= Z | G
Z ::= B | C | D | E .

Parser Generator Output

1. To reduce maintenance, collect the tables generated by the Parser Generator into a single subroutine that can be referenced externally.

Lexical Analyzer

1. Include the VOCAB and CHRTP table in (1) above.
2. Remove the order dependencies of the terminal symbols in the VOCAB and CHRTP tables.
3. Recode the analyzer in assembler language for improved speed.

Syntax Analyzer

1. Collect the state tables and other major compiler structures in a single subroutine that can be referenced externally.
2. Place the input/output tables, initialization code, and input/output termination code in SMFSIO.

3. Collect the lexical, syntactic, and semantic-diagnostic handling in a subroutine invoked only by the syntax analyzer.

4. Recode the analyzer in assembler language.

Semantic Subroutines

1. Place the generated instruction sequence, the Label Table, and the Literal/Identifier Table in the subroutine containing the major compiler structures.

2. Evaluate any arithmetic expression that involves a sequence of constants. Currently, in an arithmetic expression of the form

5 + 6 + 7 - 3 ,

the semantic subroutines would produce the sequence

```
IC   5
IC   6
ADD
IC   7
ADD
IC   3
SUB
```

which is equivalent to an IC 15. Note that the interpreter can already handle two's complement arithmetic for the 12-bit integer constant, IC. This notion could be extended to include literal operands and the concatenate operator, with the appropriate alignment and conversion code.

Note that though this improvement is rather easy to implement and often cited as a compiler optimizing technique, in practice the gain is small because such expressions are seldom generated by the user.

3. Currently, the address and branch faults (AD, BF) sequence is generated for test and branch at the end of each term. One could define a new instruction to load a branch register. This instruction, the first of each rule, would load the register with the address of the next rule. Upon encountering an end-of-term, the interpreter would then test the Binary Switch register and either continue or branch indirectly through the branch register.

4. Currently, the instruction sequence is kept in core memory until the entire form is processed. The length of the instruction sequence is calculated after the form is processed, and the length precedes the code on the output file. The length should be written as a separate file (or the file should be backspaced to write the length) to remove the artificial limit on the form's size.†

5. Remove the input/output tables from the semantic subroutines and place them in SMFSIO.

6. The routine TABLES is detachable from the semantic subroutines and can be replaced by a dummy routine to conserve space. TABLES lists (on the diagnostic file) the contents of the Label Table and Literal/Identifier Table.

7. If arithmetic expressions involving constants are evaluated by the compiler (see (2) above), it is possible to check the validity of the label for the branch forms shown below:

S(x)
F(x)
U(x)

When the operand x is an arithmetic expression involving constants alone, the semantic subroutines could check the computed value for an integer, $0 \leq n \leq 9999$.

8. If a routine is written to centralize error processing, (see (3), Syntax Analyzer Improvements), certain syntax errors could be corrected. For example, the term "(A .GE. B : UR(5+x)," contains a syntax error in the control field; the user omitted the second right parenthesis before the comma. The error-processing routine could force "recognition" of the missing right parenthesis. Two practical results are achieved. If the form contains only a few such errors, it does not have to be recompiled; by continuing the compilation, other errors can be detected and reported. Corrective actions can be taken where the error involves a terminal for a defined-type represented by a single production. In fact, any composite that reduces to a unique terminal

---

†The current limit is 2000 instructions. To increase the size, change the variables MXINSTS and CODE.

(e.g., a missing-rule delimiter at the end of a form, a missing comma between descriptors, or a missing colon before a control expression) can be corrected.

Some semantic errors can be flagged and temporarily ignored in order to compile as much as possible. Errors reported by the semantic subroutines are usually such that the instructions are non-executable. When such errors are detected, the compiler skips to the next rule. Instead, the error condition could be held in abeyance until either an uncorrectable syntax error is found or until the entire form is parsed. For example, such errors as a doubly defined label or a compiler table overflow can be treated this way.

Find Literal (FINDLT)

1. Literals currently begin on a full-word boundary, but could be aligned on a byte boundary because the interpreter is independent of boundary alignment.

File Input/Output

1. Add a new entry point in SMFSIO for the following (see Ref. 11 to understand the jargon).

   a. Open a duplex connection for a file, given the name. Establish the socket numbers† within this entry point rather than in PRSEK, where it is currently done.
   b. Issue a delete and an allocate file command for all but the source file.
   c. Issue a read command to open the source file.
   d. Attempt to get the input from the SYSIN data set if the source is not available. Write diagnostic messages accordingly.

Add a new entry point in SMFSIO to close all files. If a file error is detected, delete the object files if they exist.

---

†Socket numbers are the names of each end of ARPANET logical message paths.

2. Remove input/output dependencies in the compiler by moving the input/output tables to the subroutine containing the major compiler structures, and by executing all input/output within SMFSIO.

V. DISCUSSION

COMPILER DEVELOPMENT

A primitive version of the semantic subroutines was coded and tested using JOSS [14], a console-oriented language. JOSS is strictly algebraic and provides a limited amount of working storage.

After initial checks, the semantic routines were coded in Conversational Programming System (CPS)† [15], another console-oriented language. The lexical analyzer and the routines to manage semantic tables were coded in CPS and checked and then combined with the semantic subroutines and a crude syntax analyzer. The combined program taxed the storage limits of CPS, but a working version of the compiler was developed.

The CPS program was then translated to PL/1. In the PL/1 version of the compiler, the semantic subroutines and lexical analyzer were fully developed and tested. A skeleton syntax analyzer from the Parser Generator replaced the CPS-coded analyzer; the state tables and the input/output routines were added.

LOOKING BACK

Perhaps the compiler should have been coded directly in PL/1, rather than in intermediate forms in the other languages. Many of the limitations encountered in JOSS and CPS do not exist in PL/1. Sections of troublesome code could have been coded in CPS in order to debug them easily, and then recoded in PL/1 in parallel to the PL/1 program development.

Compiler writing systems, e. the Parser Generator, provide a skeleton compiler of the lexical and syntax analyzers as well as convenient input/output mechanisms for the compiler's input and the semantic output. They free the user to concentrate on the BNF syntax and the semantics. We used only the syntax analyzer skeleton with no major

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†CPS offers a subset of PL/1 constructs.

inconvenience. However, the greatest inconvenience was that we did not use the Parser Generator for its intended purpose--generating an XPL-coded compiler. Because our compiler was PL/1-coded, we had to go through the previously described editing process, which introduced many clerical errors.

The compiler began with a simple input/output method that reads card images and prints. Input/output code and tables are scattered throughout the compiler. Closer attention to input/output from the beginning would have prevented a number of problems that were later uncovered. Some of the suggested improvements reorganize the input/output into a centralized component.

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Appendix A

PARSER GENERATOR'S OUTPUT

```
//JOBLIB       DD             DSN=B5765.LALR,DISP=SHR
// EXEC PGM=LALR,REGION=228K
//NONTERM DD    SPACE=(CYL,9),UNIT=SYSDA
//FSMDATA       DD             SPACE=(CYL,9),UNIT=SYSDA
//PTABLES DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=400)
//SYSPRINT DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1995)
//SYSIN DD *
OPTIONS (BNF,AINPUT,GPOST.DETAILED.LALR,NOTRACE,GRAMMAR,NOSXREF)
GLUMP   FORM
FORM    RULE
        FORM RULE
RULE  LABEL INPUTSTREAM OUTPUTSTREAM :
LABEL   INTEGER
        <EMPTY>
INPUTSTREAM TERMS
       <EMPTY>
TERMS   TERM
        TERMS , TERM
OUTPUTSTREAM SEPERATOR TERMS
       <EMPTY>
TERM IDENTIFIEE ( DESCRIPTOR CONTROL )
       IDENTIFIEE
       ( DESCRIPTOR CONTROL )
       ( COMPAREXPR CONTROL )
       ( ASSGNEXPR CONTROL )
IDENTIFIEE IDENTIFIER
DESCRIPTOR REP , DATYPE , VALUE , LENGTH
CONTROL : OPTIONS
        <EMPTY>
COMPAREXPR CONCAT CONNECTIVE CONCAT
        <EMPTY>
ASSGNEXPR IDENTIFIER .<=. CONCAT
IDENTIFIER A
       B
       E
       F
       L
       O
       S
       T
       U
       V
       X
       AD
       ED
       FR
       SB
       SR
       UR
       <ALPHA ALPHANUM>
REP     #
       ARITH
       <EMPTY>
DATYPE LITYPE
       T ( IDENTIFIER )
        <EMPTY>
VALUE   CONCAT
```

```
       <EMPTY>
LENGTH ARITH
       <EMPTY>
OPTIONS TEST
      TEST , TEST
CONCAT VAL
       CONCAT || VAL
CONNECTIVE .LE.
          .LT.
          .GE.
          .GT.
          .EQ.
          .NE.
ARITH PRIMARY
       ARITH OPERATOR PRIMARY
LITYPE B
       O
       X
       F
       A
       ED
       AD
       SB
TEST <SEUR IDENT> ( ARITH )
VAL   LITYPE LITSTRING
       ARITH
PRIMARY IDENTIFIER
       L ( IDENTIFIER )
       V ( IDENTIFIER )
          INTEGER
OPERATOR +
         -
         *
         /
<SEUR IDENT> S
        F
        U
        SR
        FR
        UR
SEPERATOR :
/*
```

```
/*   THESE ARE LALR PARSING TABLES   */

DECLARE MAXR# LITERALLY '55': /* MAX READ # */

DECLARE MAXL# LITERALLY '90': /* MAX LOOK # */

DECLARE MAXP# LITERALLY '104': /* MAX PUSH # */

DECLARE MAXS# LITERALLY '194': /* MAX STATE # */

DECLARE START_STATE LITERALLY '56':

DECLARE TERMINAL# LITERALLY '40': /* # OF TERMINALS */

DECLARE VOCAB# LITERALLY '69':

DECLARE VOCAB(VOCAB#) CHARACTER INITIAL ('','(','+','*',')',';','-','/'
,',',':','#','A','B','E','F','L','O','S','T','U','V','X','||','AD','ED'
,'FR','SB','SR','UR','_|_','.<=.','.EQ.','.GE.','.GT.','.LE.','.LT.'
,'.NE.','<EMPTY>','INTEGER','LITSTRING','<ALPHA ALPHANUM>','REP','VAL'
,'FORM','RULE','TERM','TEST','ARITH','GLUMP','LABEL','TERMS','VALUE'
,'CONCAT','DATYPE','LENGTH','LITYPE','CONTROL','OPTIONS','PRIMARY'
,'OPERATOR','ASSGNEXPR','SEPERATOR','COMPAREXPR','CONNECTIVE'
,'DESCRIPTOR','IDENTIFIEE','IDENTIFIER','INPUTSTREAM','<SEUR IDENT>'
,'OUTPUTSTREAM'):

 ECLARE P# LITERALLY '90'; /* # OF PRODUCTIONS */

DECLARE STATE_NAME(MAXR#) BIT(8) INITIAL (0,0,1,1,1,1,1,1,8,8,8,8,8,9
,15,18,20,22,30,41,43,46,47,47,47,47,47,49,50,50,51,52,52,52,52,53,55
,56,56,56,56,59,60,61,62,63,64,64,65,66,66,66,66,67,68,69):

DECLARE RSIZE LITERALLY '373': /*  READ STATES INFO  */

DECLARE LSIZE LITERALLY '83': /* LOOK AHEAD STATES INFO */

DECLARE ASIZE LITERALLY '54': /* APPLY PRODUCTION STATES INFO */

DECLARE READ1(RSIZE) BIT(8) INITIAL (0,38,10,11,12,13,14,15,16,17,18,19
,20,21,23,24,25,26,27,28,38,40,10,11,12,13,14,15,16,17,18,19,20,21,23
,24,25,26,27,28,38,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
,28,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13
,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,38,40,1,11,12,13,14,15,16,17,18,19,20,21,23
,24,25,26,27,28,40,11,12,13,16,18,21,23,24,26,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,11,12,13,14,15,16
,17,18,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,1,1,1,11,12
,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,38,40,11,12,13,14,15,16
,17,18,19,20,21,23,24,25,26,27,28,38,40,8,29,38,8,2,3,6,7,2,3,6,7,2,3,6
,7,2,3,4,6,7,2,3,6,7,1,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
,28,40,8,8,8,22,31,32,33,34,35,36,22,22,22,8,39,4,4,4,4,11,12,13,14,15
,16,17,18,19,20,21,23,24,25,26,27,28,38,40,9,1,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,40,9,11,12,13,14,15,16,17,18,19,20,21,23,24
,25,26,27,28,38,40,9,9,1,30,4,4,4,9,1,5);

DECLARE LOOK1(LSIZE) BIT(8) INITIAL (0,38,0,4,8,9,0,8,0,8,0,8,0,4,9,0
,39,0,39,0,39,0,1,0,39,0,1,0,39,0,39,0,39,0,39,0,29,38,0,8,0,2,3,6,7,8
```

```
,0,8,0,2,3,6,7,0,4,9,0,5,9,0,8,0,8,0,22,0,22,0,22,0,9,0,9,0,9,0,9,0,1,0
,30,0,9,0);

/*  PUSH STATES ARE BUILT-IN TO THE INDEX TABLES  */

DECLARE APPLY1(ASIZE) BIT(8) INITIAL (0,0,0,20,0,0,0,43,0,0,8,0,0,3,0
,44,46,47,0,0,0,27,2,8,43,4,5,6,0,0,0,0,0,0,45,18,10,0,0,2,3,7,12,0,9,0
,11,0,17,0,41,0,0,0,0);

DECLARE READ2(RSIZE) BIT(8) INITIAL (0,109,147,62,63,64,132,65,66,135
,136,137,67,68,69,70,142,71,144,145,183,146,147,129,130,131,132,65,134
,135,136,137,67,139,140,141,142,143,144,145,183,146,129,130,131,132,133
,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131,132
,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131
,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130
,131,132,65,134,135,136,137,67,139,140,141,142,143,144,145,183,146,57
,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145
,146,173,169,172,170,15,171,175,174,176,62,63,64,132,65,66,135,136,137
,67,68,69,70,142,71,144,145,183,146,189,188,190,192,191,193,129,130,131
,132,65,134,135,136,137,67,139,140,141,142,143,144,145,183,146,189,188
,190,192,191,193,4,6,5,62,63,64,132,65,66,135,136,137,67,68,69,70,142
,71,144,145,183,146,62,63,64,132,65,66,135,136,137,67,68,69,70,142,71
,144,145,183,146,59,105,109,11,184,186,185,187,184,186,185,187,184,186
,185,187,184,186,177,185,187,184,186,185,187,57,129,130,131,132,133,134
,135,136,137,138,139,140,141,142,143,144,145,146,8,8,61,17,165,163,164
,161,162,166,17,17,17,60,178,121,120,119,117,129,130,131,132,65,134,135
,136,137,67,139,140,141,142,143,144,145,183,146,13,57,129,130,131,132
,133,134,135,136,137,138,139,140,141,142,143,144,145,146,13,62,63,64
,132,65,66,135,136,137,67,68,69,70,142,71,144-145,183,146,13,13,58,18
,181,182,151,194,7,108);

DECLARE LOOK2(LSIZE) BIT(8) INITIAL (0,1,91,92,93,92,2,94,3,95,9,96,10
,97,97,12,173,129,170,130,172,131,14,133,170,134,16,138,171,139,175,140
,174,141,176,143,20,20,98,21,157,22,22,22,22,148,179,148,23,24,24,24,24
,179,155,155,26,99,99,27,28,111,29,115,32,126,33,128,34,153,42,100,44
,101,46,102,47,103,48,118,49,180,53,104);

DECLARE APPLY2(ASIZE) BIT(8) INITIAL (0,0,72,107,106,78,90,80,79,55,114
,113,88,87,86,38,39,40,37,85,84,122,89,122,122,50,51,52,180,19,35,30
,123,124,81,82,83,31,45,74,75,25,77,76,150,36,158,73,160,159,168,167,41
,54,43);

DECLARE INDEX1(MAXS#) BIT(16) INITIAL (0,1,2,22,42,60,78,96,115,134,143
,162,168,187,193,194,195,196,215,234,235,237,238,242,246,250,255,259
,278,279,280,281,288,289,290,291,292,293,294,295,296,297,316,317,336
,337,356,357,358,359,360,361,362,363,364,365,1,3,7,9,11,13,16,18,20,22
,24,26,28,30,32,34,36,39,41,47,49,54,57,60,62,64,66,68,70,72,74,76,78
,80,82,110,127,149,149,152,154,156,110,112,125,125,125,125,116,1,2,2,3
,5,5,6,6,7,7,9,9,10,10,10,10,10,12,13,15,15,19,19,20,21,21,21,21,21,21
,21,21,21,21,21,21,21,21,21,21,21,21,29,29,29,30,30,30,31,31,32,32,33
,33,34,34,38,38,38,38,38,38,39,39,44,44,44,44,44,44,44,44,46,48,48,50
,50,50,50,52,52,52,52,53,53,53,53,53,53,54);

DECLARE INDEX2(MAXS#) BIT(8) INITIAL (0,1,20,20,18,18,18,19,19,9,19,6
,19,6,1,1,1,19,19,1,2,1,4,4,4,5,4,19,1,1,1,7,1,1,1,1,1,1,1,1,1,19,1,19
,1,19,1,1,1,1,1,1,1,1,1,1,2,4,2,2,2,3,2,2,2,2,2,2,2,2,2,2,3,2,6,2,5,3,3
,2,2,2,2,2,2,2,2,2,2,2,2,1,2,2,3,9,10,12,20,27,42,44,46,47,53,1,0,1,3,0
,0,0,0,0,2,1,0,4,0,3,3,3,0,6,1,0,2,0,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,3,0,0,0,0,0,0,2,0,2,0,0,0,0,0,0,2,0,0,0,0,0,0,0,0,3,1,0
,0,3,3,0,0,0,0,0,0,0,0,0,0,0,0);
```

```
/*   THE FOLLOWING IS THE INPUT GRAMMAR   */


/*      1    GLUMP ::= FORM _|_                                        */

/*      2    FORM ::= RULE                                             */
/*      3           | FORM RULE                                        */

/*      4    RULE ::= LABEL INPUTSTREAM OUTPUTSTREAM :                 */

/*      5    LABEL ::= INTEGER                                         */
/*      6            |                                                 */

/*      7    INPUTSTREAM ::= TERMS                                     */
/*      8                  |                                           */

/*      9    TERMS ::= TERM                                            */
/*     10            | TERMS , TERM                                    */

/*     11    OUTPUTSTREAM ::= SEPERATOR TERMS                          */
/*     12                   |                                          */

/*     13    TERM ::= IDENTIFIEE ( DESCRIPTOR CONTROL )                */
/*     14           | IDENTIFIEE                                       */
/*     15           | ( DESCRIPTOR CONTROL )                           */
/*     16           | ( COMPAREXPR CONTROL )                           */
/*     17           | ( ASSGNEXPR CONTROL )                            */

/*     18    IDENTIFIEE ::= IDENTIFIER                                 */

/*     19    DESCRIPTOR ::= REP , DATYPE , VALUE , LENGTH              */

/*     20    CONTROL ::= : OPTIONS                                     */
/*     21              |                                               */

/*     22    COMPAREXPR ::= CONCAT CONNECTIVE CONCAT                   */
/*     23                 |                                            */

/*     24    ASSGNEXPR ::= IDENTIFIER .<=. CONCAT                      */

/*     25    IDENTIFIER ::= A                                          */
/*     26                 | B                                          */
/*     27                 | E                                          */
/*     28                 | F                                          */
/*     29                 | L                                          */
/*     30                 | O                                          */
/*     31                 | S                                          */
/*     32                 | T                                          */
/*     33                 | U                                          */
/*     34                 | V                                          */
/*     [illegible]        | X                                          */
/*     3                  | AD                                         */
/*     37                 | ED                                         */
/*     38                 | ER                                         */
/*     39                 | SB                                         */
```

```
/*    40                    | SR                                          */
/*    41                    | UR                                          */
/*    42                    | <ALPHA ALPHANUM>                            */

/*    43    REP ::= #                                                     */
/*    44           | ARITH                                                */
/*    45           |                                                      */

/*    46    DATYPE ::= LITYPE                                             */
/*    47              | T ( IDENTIFIER )                                  */
/*    48              |                                                   */

/*    49    VALUE ::= CONCAT                                              */
/*    50             |                                                    */

/*    51    LENGTH ::= ARITH                                              */
/*    52              |                                                   */

/*    53    OPTIONS ::= TEST                                              */
/*    54               | TEST , TEST                                      */

/*    55    CONCAT ::= VAL                                                */
/*    56              | CONCAT || VAL                                     */

/*    57    CONNECTIVE ::= .LE.                                           */
/*    58                  | .LT.                                          */
/*    59                  | .GE.                                          */
/*    60                  | .GT.                                          */
/*    61                  | .EQ.                                          */
/*    62                  | .NE.                                          */

/*    63    ARITH ::= PRIMARY                                             */
/*    64             | ARITH OPERATOR PRIMARY                             */

/*    65    LITYPE ::= B                                                  */
/*    66              | O                                                 */
/*    67              | X                                                 */
/*    68              | F                                                 */
/*    69              | A                                                 */
/*    70              | FD                                                */
/*    71              | AD                                                */
/*    72              | SR                                                */

/*    73    TEST ::= <SEUR IDENT> ( ARITH )                               */

/*    74    VAL ::= LITYPE LITSTRING                                      */
/*    75           | ARITH                                                */

/*    76    PRIMARY ::= IDENTIFIER                                        */
/*    77               | L ( IDENTIFIER )                                 */
/*    78               | V ( IDENTIFIER )                                 */
/*    79               | INTEGER                                          */

/*    80    OPERATOR ::= +                                                */
/*    81                | -                                               */
/*    82                | *                                               */
/*    83                | /                                               */
```

```
/*      84    <SFUR IDENT> ::= S                          */
/*      85                   | F                          */
/*      86                   | U                          */
/*      87                   | SR                         */
/*      88                   | FR                         */
/*      89                   | UR                         */

/*      90    SEPERATOR ::= :                             */
```

```
/*   THESE ARE LALR PARSING TABLES    */
DECLARE MAXR# LITERALLY '55': /* MAX READ # */
DECLARE MAXL# LITERALLY '90': /* MAX LOOK # */
DECLARE MAXP# LITERALLY '104': /* MAX PUSH # */
DECLARE MAXS# LITERALLY '194'; /* MAX STATE # */
DECLARE START_STATE LITERALLY '56':
DECLARE TERMINAL# LITERALLY '40': /* # OF TERMINALS */
DECLARE VOCAB# LITERALLY '69':
DECLARE VOCAB(VOCAB#) CHARACTER INITIAL ('','(','+','*',')',';','-','/'
,'.',':','#','A','B','E','F','L','O','S','T','U','V','X','||','AD','ED'
,'FR','SH','SR','UR','_|_','.<=.','.EQ.','.GE.','.GT.','.LE.','.LT.'
,'.NE.','<EMPTY>','INTEGER','LITSTRING','<ALPHA ALPHANUM>','REP','VAL'
,'FORM','RULE','TERM','TEST','ARITH','GLUMP','LABEL','TERMS','VALUE'
,'CONCAT','DATYPE','LENGTH','LITYPE','CONTROL','OPTIONS','PRIMARY'
,'OPERATOR','ASSGNEXPR','SEPERATOR','COMPAREXPR','CONNECTIVE'
,'DESCRIPTOR','IDENTIFIEE','IDENTIFIER','INPUTSTREAM','<SEUR IDENT>'
,'OUTPUTSTREAM');
DECLARE P# LITERALLY '90': /* # OF PRODUCTIONS */
DECLARE STATE_NAME(MAXR#) BIT(8) INITIAL (0,0,1,1,1,1,1,1,8,8,8,8,8,9
,15,18,20,22,30,41,43,46,47,47,47,47,47,49,50,50,51,52,52,52,52,53,55
,56,56,56,56,59,60,61,62,63,64,64,65,66,66,66,66,67,68,69):
DECLARE RSIZE LITERALLY '373': /*  READ STATES INFO  */
DECLARE ASIZE LITERALLY '54': /* APPLY PRODUCTION STATES INFO */
DECLARE READ1(RSIZE) BIT(8) INITIAL (0,38,10,11,12,13,14,15,16,17,18,19
,20,21,23,24,25,26,27,28,38,40,10,11,12,13,14,15,16,17,18,19,20,21,23
,24,25,26,27,28,38,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
,28,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13
,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,38,40,1,11,12,13,14,15,16,17,18,19,20,21,23
,24,25,26,27,28,40,11,12,13,16,18,21,23,24,26,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,11,12,13,14,15,16
,17,18,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,1,1,1,11,12
,13,14,15,16,17,18,19,20,21,23,24,25,26,27,25,38,40,11,12,13,14,15,16
,17,18,19,20,21,23,24,25,26,27,28,38,40,8,29,38,8,2,3,6,7,2,3,6,7,2,3,6
,7,2,3,4,6,7,2,3,6,7,1,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
,28,40,8,8,8,22,31,32,33,34,35,36,22,22,22,8,39,4,4,4,4,11,12,13,14,15
,16,17,18,19,20,21,23,24,25,26,27,28,38,40,9,1,11,12,13,14,15,16,17,18
,19,20,21,23,24,25,26,27,28,40,9,11,12,13,14,15,16,17,18,19,20,21,23,24
,25,26,27,28,38,40,9,9,1,30,4,4,4,9,1,5):
DECLARE LOOK1(LSIZE) BIT(8) INITIAL (0,38,0,4,8,9,0,8,0,8,0,8,0, ,9,0
,39,0,39,0,39,0,1,0,39,0,1,0,39,0,39,0,39,0,39,0,29,38,0,8,0,2,3,6,7,8
,0,8,0,2,3,6,7,0,4,9,0,5,9,0,8,0,8, ,22,0,22,0,22,0,9,0,9,0,9,0,9,0,1,0
,30,0,9,0):
/*  PUSH STATES ARE BUILT-IN TO THE INDEX TABLES  */
DECLARE APPLY1(ASIZE) BI (8) INITIAL (0,0,0,20,0,0,0,43,0,0,8,0,0,3,0
,44,46,47,0,0,0,27,2,8,43,4,5,6,0,0,0,0,0,0,45,18,10,0,0,2,3,7,12,0,9,0
,11,0,17,0,41,0,0,0,0):
DECLARE READ2(RSIZE) BIT(8) INITIAL (0,109,147,62,63,64,132,65,66,135
,136,137,67,68,69,70,142,71,144,145,183,146,147,129,130,131,132,65,134
,135,136,137,67,139,140,141,142,143,144,145,183,146,129,130,131,132,133
,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131,132
,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131
,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130
,131,132,65,134,135,136,137,67,139,140,141,142,143,144,  5,183,146,57
,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145
,146,173,169,172,170,15,171,175,1. -176,62,63,64,132,65,66,135,136,137
,67,68,69,70,142,71,144,145,183,1 6,189,188,190,192,191,193,129,130,131
```

```
,132,65,134,135,136,137,67,139,140,141,142,143,144,145,183,146,189,188
,190,1[illegible],91,193,4,6,5,62,63,64,132,65,66,135,136,137,67,68,69,70,142
,71,1[illegible]45,183,146,62,63,64,132,65,66,135,136,137,67,68,69,70,142,71
,144,1[illegible]183,146,59,105,109,11,184,186,185,187,184,185,185,187,184,186
,185,18[illegible],184,186,177,185,187,184,186,185,187,57,129,130,131,132,133,134
,135,136,137,138,139,140,141,142,143,144,145,146,8,8,61,17,165,163,164
,161,162,166,17,17,17,60,178,121,120,119,117,129,130,131,132,65,134,135
,136,137,67,139,140,141,142,143,144,145,183,146,13,57,129,130,131,132
,133,134,135,136,137,138,139,140,141,142,143,144,145,146,13,62,63,64
,132,65,66,135,136,137,67,68,69,70,142,71,144,145,183,146,13,13,58,18
,181,182,151,194,7,108);
DECLARE LOOK2(LSIZE) BIT(8) INITIAL (0,1,91,92,93,92,2,94,3,95,9,96,10
,97,97,12,173,129,169,130,172,131,14,133,170,134,16,138,171,139,175,140
,174,141,176,143,20,20,98,21,157,22,22,22,22,148,179,148,23,24,24,24,24
,179,155,155,26,99,99,27,28,111,29,115,32,126,33,128,34,153,42,100,44
,101,46,102,47,103,48,118,49,180,53,104);
DECLARE APPLY2(ASIZE) BIT(8) INITIAL (0,0,72,107,106,78,90,80,79,55,114
,113,88,87,86,38,39,40,37,85,84,122,89,122,122,50,51,52,180,19,35,30
,123,124,81,82,83,31,45,74,75,25,77,76,150,36,158,73,160,159,168,167,41
,54,43);
DECLARE INDEX1(MAXS#) BIT(16) INITIAL (0,1,2,22,42,60,78,96,115,134,143
,162,168,187,193,194,195,196,215,234,235,237,238,242,246,250,255,259
,278,279,280,281,288,289,290,291,292,293,294,295,296,297,316,317,336
,337,356,357,358,359,360,361,362,363,364,365,1,3,7,9,11,13,16,18,20,22
,24,26,28,30,32,34,36,39,41,47,49,54,57,60,62,64,66,68,70,72,74,76,78
,80,82,110,127,149,149,152,154,156,110,112,125,125,125,125,116,1,2,2,3
,5,5,6,6,7,7,9,9,10,10,10,10,10,12,13,15,15,19,19,20,21,21,21,21,21,21
,21,21,21,21,21,21,21,21,21,21,21,21,29,29,29,30,30,30,31,31,32,32,33
,33,34,34,38,38,38,38,38,38,39,39,44,44,44,44,44,44,44,44,46,48,48,50
,50,50,50,52,52,52,52,53,53,53,53,53,53,54);
DECLARE INDEX2(MAXS#) BIT(8) INITIAL (0,1,20,20,18,18,18,19,19,9,19,6
,19,6,1,1,1,19,19,1,2,1,4,4,4,5,4,19,1,1,1,7,1,1,1,1,1,1,1,1,1,19,1,19
,1,19,1,1,1,1,1,1,1,1,1,1,2,4,2,2,2,3,2,2,2,2,2,2,2,2,2,2,3,2,6,2,5,3,3
,2,2,2,2,2,2,2,2,2,2,2,2,1,2,2,3,9,10,12,20,27,42,44,46,47,53,1,0,1,3,0
,0,0,0,0,2,1,0,4,0,3,3,3,0,6,1,0,2,0,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,3,0,0,0,0,0,0,2,0,2,0,0,0,0,0,0,0,2,0,0,0,0,0,0,0,0,3,1,0
,0,3,3,0,0,0,0,0,0,0,0,0,0,0,0);
```

Appendix B

INTERPRETER INSTRUCTIONS AND REPERTOIRE

INSTRUCTION DESCRIPTIONS

Literal or Identifier Reference (LD)

A LD, which points to either an entry for an identifier (variable) or a literal in the Literal/Identifier Table, is an operand in the instruction sequence. The instruction decoder pushes a LD, unmodified, onto the stack.

Integer Constant (IC)

The IC operand is a 12-bit 2's complement constant in the instruction sequence. The IC is included for efficient handling of (absolute) numbers without the indirect addressing associated with a literal reference. It is pushed on the stack unchanged.

Address Constant (AD)

The AD operand is a 12-bit positive integer that addresses an instruction in the instruction sequence. It is used only as an operand of a branch operator.

Arbitrary Replication (ARB)

The ARB operand, which indicates an indefinite replication factor† in an input term, is a constant in the instruction sequence.

Null Value (NULL)

The NULL operand in the instruction sequence indicates an omitted field in a term. It occurs only for terms that collect data from the input stream or emit data in the output stream.

---

†The arbitrary replication is denoted by the pound sign, #, in the DRS syntax.

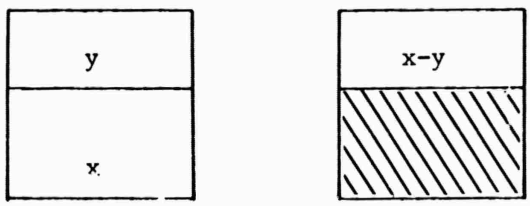
Store (STO)

A value is stored in the Literal/Identifier Table. The first two stack entries describe the location and value, respectively. Both elements are removed from the stack upon execution.

Binary Operators (ADD, SUB, MUL, DIV, CON)

The binary operators compute x <op> y, delete both x and y from the stack,[†] and push the result back onto the top of the stack:

Example: x-y



Stack before Stack after

Binary operators have no effect on the Binary Switch register. All operators except concatenate (CON) expect x and y to describe type B, O, X, AD, ED, or SB.[‡] The result is always a 32-bit type-B element. The concatenate operator expects both types x and y to be identical.

Compare (CEQ, CNE, CLE, CLT, CGE, CGT)

The compare operators (e.g., .EQ., .LT., etc.) test the values described by the first two stack entries. The second element of the stack is compared to the first. The form fails for Boolean comparators where types differ. For CEQ and CNE, the data must have identical type and length attributes. For identical types, B, O, AD, ED, and X cause

---

[†] The stack may actually contain instruction operands that describe data (rather than the data themselves). For convenience of illustration, the data rather than their descriptors are shown on the stack. For detailed formats of instructions and tables, see Sec. IV and Appendix E.

[‡] B, O, X, AD, ED, and SB represent binary, octal, hexadecimal, ASCII decimals, EBCDIC decimals, and signed binary, respectively.

binary right-justified comparison operations. Types A and E[†] cause left-justified string comparison operations. Prior to the comparison, the shorter string is right-padded with blanks.

Branch (BT, BF, BU)

The branch operators check the Binary Switch register and either increment the Instruction Counter register by one or replace it by the value described by the first stack operand. The top stack operand addresses a new Instruction Counter value in the instruction sequence. The top stack operand is removed.

Input Call (INS, IND)

The input call operators retrieve data from the input stream. They require four stack operands as shown below.

length descriptor	binary number or null
value descriptor	LD or null
data-type descriptor	binary code or null
replication descriptor	binary number, arbitrary indicator, or null

If the value-descriptor parameter is null, the input routine extracts as much data as needed from the input stream (of the required data type) to satisfy the length-descriptor and replication-descriptor requirements. If the value descriptor is not null, the input-stream data is compared to the described value. The Binary Switch is set to true if the four stack operands correctly describe the input. The stack operands are deleted. For an INS, the string obtained from the input is described by the top operand of the stack. For an IND, the stack is left empty. If the conditions are not satisfied, the stack operands are deleted and the Binary Switch is set to false.

[†] A and E represent ASCII and EBCDIC, respectively.

Upon successful application of the input-call operator, the Current Input Pointer register is advanced over the data extracted from the input stream.

Output Call (OUT)

The output-call operator emits data in the output stream. The four stack operands are the same as those described for the input call. The value is converted if the output type and the value descriptor differ. The value expression is transformed to the desired output type and fitted in the field specified by the length expression. See Ref. 6 for truncation and padding rules. The Binary Switch is unaffected.

Move Pointer (SCRP, SRCP)

These operators replace the contents of the Current Input Pointer by the contents of the Rule Input Pointer and vice versa. There are no stack operands.

Return Value (RET)

The return-value operator returns, to the originating user, the value described by the first stack operand.

Look Up Label (LUL)

The Label Table is searched for the entry referenced by the stack operand (which is a type-B value). If located, the stack entry is replaced by the relative address in the instruction sequence of the label (in the form of an AD operand); if the label is not found, the rule fails.

Load Identifier Value, Length, Type, Contents (LIV, LIL, LIT, LIC)

The top stack operand is a LD to a defined identifier. These operands extract the indicated attribute (value, length, type, contents) of the identifier and replace the first stack operand by the extracted value.

End of Term, Rule (EOT, EOR)

These pseudo operands are used to debug real-time data-reconfiguration failures. If a form fails, the interpreter scans forward in the form's instruction sequence and reports to the originating user, over the control connection, the rule and term on which the form failed. These operands carry a sequence number so that the failure may be coupled to the particular term in the specific rule that failed.

INSTRUCTION REPERTOIRE

Data Descriptors

Meaning	Mnemonic	Stack[a]	Comment
Literal or Identifier Reference	LD	$\vert$ → $\vert$LDx	This set of operands, processed by subsequent operators, is pushed unchanged into the stack.
Integer Constant	IC	$\vert$ → $\vert$ICx	
Address Constant	AD	$\vert$ → $\vert$ADx	
Arbitrary Replication	ARB	$\vert$ → $\vert$ARB	
Null Value	NULL	$\vert$ → $\vert$NULL	

Data Storing

Meaning	Mnemonic	Stack	Comment
Store	STO	$\vert$ x,y → $\vert$	y is stored in x

Binary Operators

Meaning	Mnemonic	Stack	Comment
Add	ADD	$\vert$ x,y → $\vert$y+x	
Subtract	SUB	$\vert$ x,y → $\vert$y-x	
Multiply	MUL	$\vert$ x,y → $\vert$y*x	

---

[a] We use $\vert$ to indicate the top of stack. Hence, $\vert$A,B → $\vert$C means A and B were the first two operands on the stack prior to instruction execution and C was first on the stack with A and B removed after the instruction execution.

INSTRUCTION REPERTOIRE (cont.)

Binary Operators (cont.)

Meaning	Mnemonic	Stack	Comment
Divide	DIV	$\vert\ x,y \rightarrow \vert y/x$	
Concatenate	CON	$\vert\ x,y \rightarrow \vert y \Vert x$	

Comparison

Meaning	Mnemonic	Stack	Comment
Equal	CEQ	$\vert\ x,y \rightarrow \vert$	For each, the comparison y comp x is made and the binary switch set accordingly.
Not Equal	CNE	$\vert\ x,y \rightarrow \vert$	
Less than or Equal	CLE	$\vert\ x,y \rightarrow \vert$	
Less than	CLT	$\vert\ x,y \rightarrow \vert$	
Greater than or Equal	CGE	$\vert\ x,y \rightarrow \vert$	
Greater than	CGT	$\vert\ x,y \rightarrow \vert$	

Branching

Meaning	Mnemonic	Stack	Comment
True	ET	$\vert ADx \rightarrow \vert$	The instruction counter is set to ADx if the branch is taken.

INSTRUCTION REPERTOIRE (cont.)

Branching (cont.)

Meaning	Mnemonic	Stack	Comment
False	BF	$\vert$ADx → $\vert$	
Unconditional	BU	$\vert$ADx → $\vert$	

I/O of Data Stream

Meaning	Mnemonic	Stack	Comment
Input and Save	INS	$\vert$Len,Val,Type,Rep → $\vert$ LDx	The stack has a pointer to value found in input stream.
Input and Discard	IND	$\vert$Len,Val,Type,Rep → $\vert$	The binary switch is set for both input calls.
Emit	OUT	$\vert$Len,Val,Type,Rep → $\vert$	

Input Pointer Register Manipulation

Meaning	Mnemonic	Stack	Comment
Current → Rule	SCRP	None	The rule input pointer is set to the current input pointer.
Rule → Current	SRCP	None	The current input pointer is reset to the rule input pointer.

INSTRUCTION REPERTOIRE (cont.)

Form Execution Termination

Meaning	Mnemonic	Stack	Comment
Return Value	RET	|x → |	x is returned to the form initiator.

Label Table Search

Meaning	Mnemonic	Stack	Comment
Find Label	LUL	|x → |ADx	The address of the numeric label x is put on the stack.

Data Loading

Meaning	Mnemonic	Stack	Comment
Load Contents	LIC	|LDx → |LIC(LDx)	The contents of x are put on the stack.
Load Value	LIV	|LDx → |LIV(LDx)	Value used to convert from decimal character to binary.
Load Length	LIL	|LDx → |LIL(LDx)	
Load Type	LIT	|LDx → |LIT(LDx)	

Debugging Aids

Meaning	Mnemonic	Stack	Comment
Term End	EOT	None	Used by the interpreter to indicate locations of form errors.
Rule End	EOR	None	

Appendix C

DRS COMPILER LISTINGS

```
COMPOOL: PROCEDURE;



     /* VARIABLE CONTROLS TRACING OPTION.  TRACE=1 ==> TRACE */
     /*                                    TRACE=0 ==> NO TRACE */

 DCL TRACE BIN FIXED (31) STATIC EXT INITIAL (0);


 /*   THESE ARE LALR PARSING TABLES    */

 DCL MAXR# BIN FIXED (15) STATIC EXT INIT (55);
 DCL MAXL# BIN FIXED (15) STATIC EXT INIT (90);
 DCL MAXP# BIN FIXED (15) STATIC EXT INIT (104);
 DCL START_STATE BIN FIXED (15) STATIC EXT INIT (56);
 DCL READ1(373) BIN FIXED (15) STATIC EXT INIT
                                    (38,10,11,12,13,14,15,16,17,18,19
 ,20,21,23,24,25,26,27,28,38,40,10,11,12,13,14,15,16,17,18,19,20,21,23
 ,24,25,26,27,28,38,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
 ,28,40,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13
 ,14,15,16,17,18,19,20,21,23,24,25,26,27,28,40,11,12,13,14,15,16,17,18
 ,19,20,21,23,24,25,26,27,28,38,40,1,11,12,13,14,1[illegible]17,18,19,20,21,23
 ,24,25,26,27,28,40,11,12,13,16,18,21,23,24,26,11,12,13,[illegible]5,16,17,18
 ,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,11,12,13,14,15,16
 ,17,18,19,20,21,23,24,25,26,27,28,38,40,14,17,19,25,27,28,1,1,1,11,12
 ,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,38,40,11,12,13,14,15,16
 ,17,18,19,20,21,23,24,25,26,27,28,38,40,8,29,38,8,2,3,6,7,2,3,6,7,2,3,6
 ,7,2,3,4,6,7,2,3,6,7,1,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27
 ,28,40,8,8,8,22,31,32,33,34,35,36,22,22,22,8,39,4,4,4,4,11,12,13,14,15
 ,16,17,18,19,20,21,23,24,25,26,27,28,38,40,9,1,11,12,13,14,15,16,17,18
 ,19,20,21,23,24,25,26,27,28,40,9,11,12,13,14,15,16,17,18,19,20,21,23,24
 ,25,26,27,28,38,40,9,9,1,30,4,4,4,9,1,5);
 DCL LOOK1(83) BIN FIXED (15) STATIC EXT INIT
                                    (38,0,4,8,9,0,8,0,8,0,8,0,4,9,0
 ,39,0,39,0,39,0,1,0,39,0,1,0,39,0,39,0,39,0,39,0,29,38,0,8,0,2,3,6,7,8
 ,0,8,0,2,3,6,7,0,4,9,0,5,9,0,8,0,8,0,22,0,22,0,22,0,9,0,9,0,9,0,9,0,1,0
 ,30,0,9,0);
 DCL APPLY1(54) BIN FIXED (15) STATIC EXT INIT
                                     (0,0,20,0,0,0,43,0,0,8,0,0,3,0
 ,44,46,47,0,0,0,27,2,8,43,4,5,6,0,0,0,0,0,0,45,18,10,0,0,2,3,7,12,0,9,0
 ,11,0,17,0,41,0,0,0,0);
 DCL READ2(373) BIN FIXED (15) STATIC EXT INIT
                                    (109,147,62,63,64,132,65,66,135
 ,136,137,67,68,69,70,142,71,144,145,183,146,147,129,130,131,132,65,134
 ,135,136,137,67,139,140,141,142,143,144,145,183,146,129,130,131,132,133
 ,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131,132
 ,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130,131
 ,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,129,130
 ,131,132,65,134,135,136,137,67,139,140,141,142,143,144,145,183,146,57
 ,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145
 ,146,173,169,172,170,15,171,175,174,176,62,63,64,132,65,66,135,136,137
 ,67,68,69,70,142,71,144,145,183,146,189,188,190,192,191,193,129,130,131
 ,132,65,134,135,136,137,67,139,140,141,142,143,144,145,183,146,189,188
 ,190,192,191,193,4,6,5,62,63,64,132,65,66,135,136,137,67,68,69,70,142
 ,71,144,145,183,146,62,63,64,132,65,66,135,136,137,67,68,69,70,142,71
 ,144,145,183,146,59,105,109,11,184,186,185,187,184,186,185,187,184,186
 ,185,187,184,186,177,185,187,184,186,185,187,57,129,130,131,132,133,134
```

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,135,136,137,138,139,140,141,142,143,144,145,146,8,8,61,17,165,163,164
,161,162,166,17,17,17,60,178,121,120,119,117,129,130,131,132,65,134,135
,136,137,67,139,140,141,142,143,144,145,183,146,13,57,129,130,131,132
,133,134,135,136,137,138,139,140,141,142,143,144,145,146,13,62,63,64
,132,65,66,135,136,137,67,68,69,70,142,71,144,145,183,146,13,13,58,18
,181,182,151,194,7,108);
DCL LOOK2(83) BIN FIXED (15) STATIC EXT INIT
                                            (1,91,92,93,92,2,94,3,95,9,96,10
,97,97,12,173,129,169,130,172,131,14,133,170,134,16,138,171,139,175,14
,174,141,176,143,20,20,98,21,157,22,22,22,22,148,179,148,23,24,24,24,24
,179,155,155,26,99,99,27,28,111,29,115,32,126,33,128,34,153,42,100,44
,101,46,102,47,103,48,118,49,180,53,104);
DCL APPLY2(54) BIN FIXED (15) STATIC EXT INIT
                                            (0,72,107,106,78,90,80,79,55,114
,113,88,87,86,38,39,40,37,85,84,122,89,122,122,50,51,52,180,19,35,30
,123,124,81,82,83,31,45,74,75,25,77,76,150,36,158,73,160,159,168,167,41
,54,43);

/*  PUSH STATES ARE BUILT-IN TO THE INDEX TABLES  */

DCL INDEX1(194) BIN FIXED (15) STATIC EXT INIT
                                            (1,2,22,42,60,78,96,115,134,143
,162,168,187,193,194,195,196,215,234,235,237,238,242,246,250,255,259
,278,279,280,281,288,289,290,291,292,293,294,295,296,297,316,317,336
,337,356,357,358,359,360,361,362,363,364,365,1,3,7,9,11,13,16,18,20,22
,24,26,28,30,32,34,36,39,41,47,49,54,57,60,62,64,66,68,70,72,74,76,78
,80,82,110,127,149,149,152,154,156,110,112,125,125,125,125,116,1,2,2,3
,5,5,6,6,7,7,9,9,10,10,10,10,10,12,13,15,15,19,19,20,21,21,21,21,21,21
,21,21,21,21,21,21,21,21,21,21,21,21,29,29,29,30,30,30,31,31,32,32,33
,33,34,34,38,38,38,38,38,38,39,39,44,44,44,44,44,44,44,44,46,48,48,50
,50,50,50,52,52,52,52,53,53,53,53,53,53,54);
DCL INDEX2(194) BIN FIXED (15) STATIC EXT INIT
                                            (1,20,20,[illegible],18,18,19,19,9,19,6
,19,6,1,1,1,19,19,1,2,1,4,4,4,5,4,19,1,1,1,7,1[illegible],1,1,1,1,1,1,1,19,1,19
,1,19,1,1,1,1,1,1,1,1,1,1,2,4,2,2,2,3,2,2,2,2,2,2,2,2,2,3,2,6,2,5,3,3
,2,2,2,2,2,2,2,2,2,2,2,2,1,2,2,3,9,10,12,20,27,42,44,46,47,53,1,0,1,3,0
,0,0,0,0,2,1,0,4,0,3,3,3,0,6,1,0,2,0,2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,3,0,0,0,0,0,0,2,0,2,0,0,0,0,0,0,2,0,0,0,0,0,0,0,0,3,1,0
,0,3,3,0,0,0,0,0,0,0,0,0,0,0,0);


DCL TERMINAL# BIN FIXED (15) STATIC EXT INIT (40);
DCL VOCAB# BIN FIXED (15) STATIC EXT INIT (69);
DCL P# BIN FIXED (15) STATIC EXT INIT (90);
END COMPOOL;
```

```
PRSER: PROCEDURE (PRM) OPTIONS(MAIN);


       /* VARIABLES HOLD PARM FROM EXEC CARD */

       DCL PRM CHAR (100) VAR;
       DCL PARM CHAR (100) VAR EXT STATIC;


       /* TABLES OUTPUT FROM PARSER GENERATOR */

       DCL MAXR# BIN FIXED (15) STATIC EXT;
       DCL MAXL# BIN FIXED (15) STATIC EXT;
       DCL MAXP# BIN FIXED (15) STATIC EXT;
       DCL START_STATE BIN FIXED (15) STATIC EXT;
       DCL READ1(373) BIN FIXED (15) STATIC EXT;
       DCL LOOK1(83) BIN FIXED (15) STATIC EXT;
       DCL APPLY1(54) BIN FIXED (15) STATIC EXT;
       DCL READ2(373) BIN FIXED (15) STATIC EXT;
       DCL LOOK2(83) BIN FIXED (15) STATIC EXT;
       DCL APPLY2(54) BIN FIXED (15) STATIC EXT;
       DCL INDEX1(194) BIN FIXED (15) STATIC EXT;
       DCL INDEX2(194) BIN FIXED (15) STATIC EXT;


       /* ROUTINES INVOKED BY PRSER */

       DCL DISPLAY ENTRY (CHAR (72) VAR);
       DCL LXANLZ ENTRY RETURNS(BIN FIXED (15));
       DCL SMNTC ENTRY (BIN FIXED) RETURNS (BIN FIXED (15));
       DCL SMFOIO ENTRY ((2) BIN FIXED (31), BIN FIXED (31),
       (2) BIN FIXED (31));
       DCL SMFCIO ENTRY ((2) BIN FIXED (31));
       DCL SMFLIO ENTRY ;


       /* TABLES FOR SMFS  */

       DCL CMPLT1(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL (1,1);
       DCL CMPLT2(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL (2,2);
       DCL CMPLT3(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL (3,3);
       DCL CMPLT4(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL (4,4);

       DCL LCLSKT1 BIN FIXED (31) ALIGNED STATIC INITIAL (4098);
       DCL LCLSKT2 BIN FIXED (31) ALIGNED STATIC INITIAL (4102);
       DCL LCLSKT3 BIN FIXED (31) ALIGNED STATIC INITIAL (4106);
       DCL LCLSKT4 BIN FIXED (31) ALIGNED STATIC INITIAL (4110);

       DCL WRKSPS1(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL ((2)0) ;
       DCL WRKSPS2(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL ((2)0);
       DCL WRKSPS3(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL ((2)0);
       DCL WRKSPS4(2) BIN FIXED (31) ALIGNED STATIC EXT INITIAL ((2)0);

       DCL 1 CR8DIAG STATIC UNALIGNED EXT,
       2 OPCD BIT (8) INITIAL ('00000010'B),
       2 FLGS BIT (16) INITIAL ('0000000001000000'B),
       2 NLNG BIT (8) INITIAL ('00100100'B),
```

```
2 FNAM CHAR (36) INITIAL ('').
2 FLNG BIN FIXED (31) INITIAL (88000);

DCL 1 CR8OBJI STATIC UNALIGNED EXT,
2 OPCD BIT (8) INITIAL ('00000010'B),
2 FLGS BIT (16) INITIAL (0),
2 NLNG BIT (8) INITIAL ('00100100'B),
2 FNAM CHAR (36) INITIAL (''),
2 FLNG BIN FIXED (31) INITIAL (3300);

DCL 1 CR8OBJT STATIC UNALIGNED EXT,
2 OPCD BIT (8) INITIAL ('00000010'B),
2 FLGS BIT (16) INITIAL (0),
2 NLNG BIT (8) INITIAL ('00100100'B),
2 FNAM CHAR (36) INITIAL (''),
2 FLNG BIN FIXED (31) INITIAL (48000);

DCL 1 RDSRCE STATIC UNALIGNED EXT,
2 OPCD BIT (8) INITIAL ('00000101'B),
2 FLGS BIT (16) INITIAL (0),
2 NLNG BIT (8) INITIAL ('00100100'B),
2 FNAM CHAR (36) INITIAL (''),
2 DLNG BIN FIXED (31) INITIAL (0);

DCL 1 WRTOBJT1 STATIC EXT,
2 OPCD BIT (8) UNALIGNED INITIAL ('00000011'B),
2 FLGS BIT (16) UNALIGNED INITIAL (0),
2 NLNG BIT (8) UNALIGNED INITIAL ('00100100'B),
2 FNAM CHAR (36) UNALIGNED INITIAL (''),
2 DLNG BIN FIXED (31) ALIGNED INITIAL (0),
2 BYTLLBT BIN FIXED (15) ALIGNED INITIAL (0),
2 LBTN3(0:199),
     3 LBLVLU BIN (15) FIXED ALIGNED INITIAL ((200)0),
     3 LBLOFST BIN (15) FIXED ALIGNED INITIAL ((200)0);

DCL 1 WRTOBJI STATIC EXT,
2 OPCD BIT (8) UNALIGNED INITIAL ('00000011'B),
2 FLGS BIT (16) UNALIGNED INITIAL (0).
2 NLNG BIT (8) UNALIGNED INITIAL ('00100100'B).
2 FNAM CHAR (36) UNALIGNED INITIAL (''),
2 DLNG BIN FIXED (31) ALIGNED INITIAL (0),
2 BYTLCDT BIN FIXED (15) ALIGNED INITIAL (0),
2 CODE(0:1999) BIN FIXED (15) ALIGNED INITIAL ((2000)0);

DCL 1 DLTFILE STATIC UNALIGNED EXT,
2 OPCD BIT (8) INITIAL ('00000111'B),
2 FLGS BIT (16) INITIAL (0),
2 NLNG BIT (8) INITIAL ('00100100'B),
2 FNAM CHAR (36) INITIAL (''),
2 FLNG BIT (32) INITIAL (0);




/*  SHARED VARIABLES */

DCL STACKSIZ BIN FIXED STATIC EXT INITIAL (40);
```

```
        DCL STATE_STACK(40) BIN FIXED (15) STATIC INITIAL ((40)0);
        DCL BCDVLU CHAR(256) VAR EXT STATIC INITIAL ('');
        DCL SYMBOL(0:1) CHAR (256) VAR STATIC EXT INIT ((2)'');
        DCL (IC,ICO) BIN FIXED STATIC EXT;
        DCL TRACE BIN FIXED (31) STATIC EXT;


        /* LOCAL VARIABLES */

        DCL STATE BIN STATIC FIXED INITIAL(0);
        DCL READIT BIN STATIC FIXED INITIAL(1);
        DCL SP BIN STATIC FIXED INITIAL (0);
        DCL MP BIN STATIC FIXED;
        DCL TOKEN BIN STATIC FIXED;
        DCL (I,J) BIN FIXED STATIC;
        DCL ERROR BIN FIXED STATIC INITIAL (0);


        /* INITIALIZE AT THIS POINT*/

        /* MAKE PARM FROM EXEC CARD AVAILABLE TO ALL ROUTINES */

        PARM = PRM;

        /* INITIALIZE FILES */

        RDSRCE.FNAM = 'DRS SRCE '||PARM;
        CR8DIAG.FNAM = 'DRS DIAG '||PARM;
        CR8OBJI.FNAM = 'DRS OBJI '||PARM;
        CR8OBJT.FNAM = 'DRS OBJT '||PARM;
        CALL SMFOIO(CMPLT1,LCLSKT1,WRKSPS1);
        IF CMPLT1(1)+CMPLT1(2) ¬= 0 THEN GO TO ABORT;
        CALL SMFOIO(CMPLT2,LCLSKT2,WRKSPS2);
        CALL SMFOIO(CMPLT3,LCLSKT3,WRKSPS3);
        CALL SMFOIO(CMPLT4,LCLSKT4,WRKSPS4);
        DLTFILE.FNAM = CR8DIAG.FNAM;
        CALL SMFLIO(CMPLT2,DLTFILE);
        DLTFILE.FNAM = CR8OBJI.FNAM;
        CALL SMFLIO(CMPLT3,DLTFILE);
        DLTFILE.FNAM = CR8OBJT.FNAM;
        CALL SMFLIO(CMPLT4,DLTFILE);
        CALL SMFLIO(CMPLT1,RDSRCE);
        CALL SMFLIO(CMPLT2,CR8DIAG);
        CALL SMFLIO(CMPLT3,CR8OBJI);
        CALL SMFLIO(CMPLT4,CR8OBJT);
        WRTOBJI.FNAM = CR8OBJI.FNAM;
        WRTOBJT1.FNAM = CR8OBJT.FNAM;


        /* START COMPILE LOOP */

        READIT = .
RESTART:
        SP = 0;
        STATE = START_STATE;
COMP:
        DO WHILE ('1'B);
```

```
        IF STATE <= MAXR# THEN
        DO;
        SP = SP+1;
        IF SP >= STACKSIZ THEN GO TO ENDIT;
        STATE_STACK(SP) = STATE;
        I = INDEX1(STATE);
        IF READIT = 1 THEN
        DO;
        SYMBOL(0) = SYMBOL(1);
        TOKEN = LXANLZ;
        SYMBOL(1) = BCDVLU;
        READIT = 0;
        IF TOKEN < 0 THEN GO TO LXLAERR;
        END;
        DO I = I TO I+INDEX2(STATE)-1;
        IF READ1(I) = TOKEN THEN
        DO;
        STATE = READ2(I);
        SYMBOL(0) = SYMBOL(1);
        READIT = 1;
        GO TO COMP;
        END;
        END;
LXLAERR:
        CALL DISPLAY(
        '** ERROR IN TEXT BEGINNING '''||BCDVLU||'''. **');
SMNTCERR:
        CALL DISPLAY(
        '** THE RULE CONTAINING THE ERROR IS IGNORED **');
        ERROR = 1;
        ICO = IC;
SKIP:
        READIT = 1;
SKIPMORE:
        IF TOKEN <= 0 | TOKEN = 29 THEN GO TO CLOSEOUT;
        SYMBOL(1) = BCDVLU;
        IF READIT = 0 THEN GO TO RESTART;
        IF TOKEN = 5 THEN READIT = 0;
        TOKEN = LXANLZ;
        GO TO SKIPMORE;
        END;
        ELSE
        /*TEST FOR APPLY STATE*/
        IF STATE > MAXP# THEN
        DO;
        MP = SP-INDEX2(STATE);
        BCDVLU = SYMBOL(0);
        IF SMNTC(STATE-MAXP#) < 0 THEN GO TO SMNTCERR;
        SP = MP;
        I = INDEX1(STATE);
        J = STATE_STACK(SP);
        DO WHILE (APPLY1(I) ¬= 0);
        IF J = APPLY1(I) THEN GO TO TOP_MATCH;
        I = I+1;
        END;
TOP_MATCH:
        IF APPLY2(I) = 0 THEN GO TO CLOSEOUT;
```

```
        STATE = APPLY2(I);
        END;
        ELSE
        /*TEST FOR LOOK STATE*/
        IF STATE <= MAXL# THEN
        DO;
        I = INDEX1(STATE);
        IF READIT = 1 THEN
        DO;
        SYMBOL(0) = SYMBOL(1);
        TOKEN = LXANLZ;
        SYMBOL(1) = BCDVLU;
        READIT = 0;
        IF TOKEN < 0 THEN GO TO LXLAERR;
        END;
        DO WHILE (LOOK1(I) ¬= 0);
        IF LOOK1(I) = TOKEN THEN GO TO LOOK;
        I = I+1;
        END;
LOOK:
        STATE = LOOK2(I);
        END;
        ELSE
        /*MUST BE PUSH STATE*/
        DO;
        SP = SP+1;
        IF SP >= STACKSIZ THEN GO TO ENDIT;
        STATE_STACK(SP) = INDEX2(STATE);
        STATE = INDEX1(STATE);
        END;
        END;


        /* CLOSE OUT COMPILER */

ENDIT:
        CALL DISPLAY('STATE STACK OVERFLOW. MAX IS'||STACKSIZ);
CLOSEOUT:
        CALL DISPLAY('COMPILATION TERMINATED');
        IF ERROR ¬= 0 THEN
        DO;
        CALL DISPLAY(
        'THE INSTRUCTION, LABEL, AND IDENTIFIER/LITERAL TABLES WILL NOT');
        CALL DISPLAY(
        'BE WRITTEN BECAUSE OF THE PREVIOUSLY NOTED ERRORS.');
        DLTFILE.FNAM = CR80BJI.FNAM;
        CALL SMFLIO(CMPLT3,DLTFILE);
        DLTFILE.FNAM = CR80BJT.FNAM;
        CALL SMFLIO(CMPLT4,DLTFILE);
        END;
        ELSE
        DO;
        CALL SMFCIO(CMPLT3);
        CALL SMFCIO(CMPLT4);
        END;
        CALL SMFCIO(CMPLT2);
        RETURN;
```

```
ABORT:
       CALL DISPLAY('NO INPUT AVAILABLE. CAN''T COMPILE');
       END PRSER:
```

```
LXANLZ : PROCEDURE RETURNS( BINARY FIXED (15));

      /* SHARED VARIABLES */

      DCL INPUT CHAR (84) VAR ALIGNED STATIC EXT;
      DCL TRACE BIN FIXED (31) STATIC EXT ;
      DCL TERMINAL# BIN FIXED (15) STATIC EXT;
      DCL BCDVLU CHAR(256) VAR STATIC EXT INITIAL ('');
      DCL LINESZ BIN FIXED (15) STATIC EXT;
      DCL LINE CHAR (332) VAR ALIGNED STATIC EXT;


      /* ROUTINES INVOKED BY LXANLZ */

      DCL DISPLAY ENTRY (CHAR (72) VAR);
      DCL READ ENTRY RETURNS(BIN FIXED (15));
      DCL INDX ENTRY (CHAR(256) VAR) RETURNS(BIN FIXED (15));
      DCL VREY ENTRY (CHAR(256) VAR) RETURNS(BIN FIXED (15));


      /* LOCAL VARIABLES */

      DCL CHRTP CHAR (50) STATIC
      INITIAL (' (+*);-/,:#".|ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789');
      DCL NDX(5) BIN FIXED STATIC INITIAL
      (1,85,113,117,145);
      DCL LNGTH BIN FIXED (15) STATIC INITIAL (0);
      DCL VOCAB CHAR (144) STATIC ALIGNED EXT INITIAL
('(   +   *   )   ;   -   /   ,   :   #   A   B   E   F   L   O   S   T
  U   V   X   ||  AD  ED  ER  SB  SR  UR  _|_ .<=..EQ..GE..GT..LE..LT..N
E.');
      DECLARE RESULT BIN FIXED STATIC ;
      DECLARE (TEMP1,TEMP2) BIN FIXED STATIC ;
      DCL BCMDLMTR CHAR(2) STATIC INIT ('/*');
      DCL ECMDLMTR CHAR(2) STATIC INIT ('*/');
      DCL LTDLMTR CHAR(1) STATIC INIT ('"');
      DCL BLNK84 CHAR (84) STATIC INITIAL (' ');


      /* BEGIN LEXICAL ANALYSIS */

RESTART:
      TEMP1 = VREY(' ');
      IF TEMP1 = 0 THEN GO TO EOF;
      RESULT = INDEX(CHRTP,SUBSTR(INPUT,1,1));
      IF RESULT=0 THEN GO TO RESTART;
      IF RESULT<15 THEN GO TO LITRL;
      IF RESULT<=40 THEN TEMP1=15;
      ELSE TEMP1 = 41;
      TEMP2 = VREY(SUBSTR(CHRTP,TEMP1));
      RESULT=38;
      IF TEMP1=41 THEN GO TO FORM;
      RESULT=40;
      IF LNGTH>2 THEN GO TO FORM;
      TEMP2 = NDX(LNGTH);
      TEMP1 = INDEX(SUBSTR(VOCAB,TEMP2,NDX(LNGTH+1)-TEMP2),BCDVLU);
      IF TEMP1 ¬= 0 THEN RESULT = (TEMP1+TEMP2+2)/4;
```

```
      GO TO FORM;
LITRL:
      IF RESULT=12 THEN GO TO LTSTR;
      IF SUBSTR(INPUT,1,2) = BCMDLMTR THEN GO TO COMMENT;
      LNGTH = 1;
      IF RESULT = 13 THEN LNGTH = 4;
      IF RESULT = 14 THEN LNGTH = 2;
      TEMP2 = NDX(LNGTH);
      TEMP1 = INDEX(SUBSTR(VOCAB,TEMP2,NDX(LNGTH+1)-TEMP2),
      SUBSTR(INPUT,1,LNGTH));
      IF TEMP1 ¬= 0 THEN RESULT = (TEMP1+TEMP2+2)/4;
      ELSE
      DO;
      RESULT = -1;
      LNGTH = 1;
      END;
      TEMP1 = INDX(SUBSTR(INPUT,1,LNGTH));
FORM:
      LINE = LINE||BCDVLU;
      GO TO COVER;
COMMENT:
      RESULT = -1;
      INPUT = SUBSTR(INPUT,3);
      TEMP1 = INDX(ECMDLMTR);
      LINE = LINE||BCMDLMTR||BCDVLU;
      IF TEMP1 = 0 THEN GO TO COVER;
      RESULT = 100;
      GO TO COVER;
LTSTR:
      RESULT = -1;
      INPUT = SUBSTR(INPUT,2);
      TEMP1 = INDX(LTDLMTR);
      LINE = LINE||LTDLMTR||BCDVLU;
      IF TEMP1 = 0 THEN GO TO COVER;
      RESULT=39;
      BCDVLU = SUBSTR(BCDVLU,1,LNGTH-1);
COVER:
      LINE = LINE||' ';
      IF LENGTH(LINE) > LINESZ THEN
      DO;
      CALL DISPLAY(SUBSTR(LINE,1,LINESZ));
      LINE = SUBSTR(LINE,LINESZ+1);
      GO TO COVER;
      END;
      IF RESULT = 100 THEN GO TO RESTART;
      IF RESULT = 5 | RESULT = 29 THEN
      DO;
      CALL DISPLAY(LINE);
      LINE = '';
      END;
      RETURN(RESULT);
EOF:
      RESULT = 29;
      BCDVLU = '';
      LINE = LINE||'/* END OF FORM */';
      GO TO COVER;
```

```

VRFY: PROCEDURE(TEXT) RETURNS(BIN FIXED (15));
      DCL TEXT CHAR (256) VAR;
      DCL (TEMP1,TEMP2,TEMP3) BIN FIXED (15) STATIC;

      /* GIVE A TARGET STRING TO SEARCH FOR OR VERIFY */
      /* ON RETURN:  INPUT CONTAINS THE STRING THAT FOLLOWS THE */
      /*             TARGET--INCLUDING THE TARGET (OR STRING NOT IN */
      /*             THE VERIFY LIST.  BCDVLU CONTAINS THE SCANNED */
      /*             STRING--NOT INCLUDING THE NON-VERIFIED */
      /*             SYMBOL.  THE FUNCTION VALUE WILL BE ZERO IF THE */
      /*             INPUT RAN OUT OR THE POSITION OF THE TARGET OR */
      /*             NON-VERIFIED STRING, 1, IF IT DID NOT. */
      /*             FUNCTION VALUE WILL BE ZERO IF THE INPUT RAN OUT */
      /*             OR THE POSITION OF THE TARGET OR NON-VERIFIED */
      /*             STRING. */

      TEMP3 = 1;
      GO TO SCAN;
INDX: ENTRY(TEXT) RETURNS(BIN FIXED (15));
      TEMP3 = 2;
SCAN:
      BCDVLU = '';
MORE:
      IF TEMP3 = 1 THEN TEMP2 = VERIFY(INPUT,TEXT);
      ELSE TEMP2 = INDEX(INPUT,TEXT);
      IF TEMP2 = 0 THEN
      DO;
      BCDVLU = BCDVLU||INPUT;
      INPUT = BLNK84;
      IF READ ¬= 0 THEN GO TO MORE;
      END;
      ELSE
      DO;
      IF TEMP3 = 2 THEN TEMP2 = TEMP2+LENGTH(TEXT);
      IF TEMP2 > 1 THEN
      DO;
      BCDVLU = BCDVLU||SUBSTR(INPUT,1,TEMP2-1);
      INPUT = SUBSTR(INPUT,TEMP2);
      TEMP2 = 1;
      END;
      END;
      LNGTH = LENGTH(BCDVLU);
      RETURN(TEMP2);
      END VRFY;
      END LXANLZ;
```

```
SMNTC: PROCEDURE(COMPNT) RETURNS (BIN FIXED (15));
      DCL COMPNT BIN FIXED (15) ;


      /* PARAMETERS FOR TABLE SIZES */

      DCL LBLFLR BIN FIXED (15) STATIC EXT INIT (0);
      DCL LBLCLNG BIN FIXED (15) STATIC EXT INIT (9999);
      DCL IDLNGTH BIN FIXED (15) STATIC EXT INIT (4);
      DCL MXSTKSZ BIN FIXED (15) STATIC  EXT INIT (15);
      DCL MXINSTS BIN FIXED (15) STATIC EXT INIT (2000);
      DCL MXLBLS BIN FIXED (15) STATIC EXT INIT (200);
      DCL MXNDXS BIN FIXED (15) STATIC E   INIT (256);
      DCL MXIDS BIN FIXED (15) STATIC EXT INIT (512);
      DCL MXLITS BIN FIXED (15) STATIC EXT INIT (2000);


      /* SHARED VARIABLES */

      DCL TRACE BIN FIXED (31) STATIC EXT;
      DCL TERMINAL# BIN FIXED (15) STATIC EXT;
      DCL VOCAB# BIN FIXED (15) STATIC EXT;
      DCL P# BIN FIXED (15) STATIC EXT;
      DCL ICO BIN FIXED STATIC EXT INITIAL (-1);
      DCL IC  BIN FIXED STATIC EXT INITIAL (-1);
      DCL NMLBS BIN FIXED STATIC EXT INITIAL (-1);
      DCL NMIDS BIN FIXED STATIC EXT INITIAL (-1);
      DCL LTEND BIN FIXED STATIC EXT INITIAL (0);
      DCL NMNDXS BIN FIXED STATIC EXT INITIAL (-1);
      DCL BCDVLU CHAR(256) VAR EXT;


      /* ROUTINES INVOKED BY SMNTC */

      DCL SPUCODE ENTRY;
      DCL SMFLIO ENTRY;
      DCL SMFSIO ENTRY;
      DCL DISPLAY ENTRY (CHAR(72) VAR);
      DCL FINDLT ENTRY (CHAR(256) VAR, BIN FIXED (15))
      RETURNS(BIN FIXED (15));
      DCL FINDID ENTRY (CHAR(4) VAR) RETURNS(BIN FIXED (15));
      DCL FINDLB ENTRY (BIN FIXED (15)) RETURNS(BIN FIXED (15));
      DCL GNRTR ENTRY (BIN FIXED (15)) RETURNS (BIN FIXED (15));
      DCL GETIDNT ENTRY RETURNS (BIN FIXED (15));


      /* VARIABLES FOR SMFS */


      DCL CMPLT3(2) BIN FIXED (31) ALIGNED STATIC EXT;
      DCL CMPLT4(2) BIN FIXED (31) ALIGNED STATIC EXT;
      DCL 1 WRTOBJI STATIC  EXT,
      2 OPCD BIT (8) UNALIGNED,
      2 FLGS BIT (16) UNALIGNED,
      2 NLNG BIT (8) UNALIGNED,
      2 FNAM CHAR (36) UNALIGNED,
      2 DLNG BIN FIXED (31) ALIGNED,
```

```
2 BYTLCDT BIN FIXED (15) ALIGNED,
2 CODE(0:1999) BIN FIXED (15) ALIGNED;

DCL 1 WRTOBJT1 STATIC EXT,
2 OPCD BIT (8) UNALIGNED,
2 FLGS BIT (16) UNALIGNED,
2 NLNG BIT (8) UNALIGNED,
2 FNAM CHAR (36) UNALIGNED,
2 DLNG BIN FIXED (31) ALIGNED,
2 BYTLLBT BIN FIXED (15) ALIGNED,
2 LBTN3(0:199),
    3 LBLVLU BIN FIXED (15) ALIGNED INITIAL ((200)0),
    3 LBLOFST BIN FIXED (15) ALIGNED INITIAL ((200)0);

DCL 1 WRTOBJT2 STATIC EXT,
2 DUMMY BIT (8) ALIGNED INITIAL (0),
2 OPCD BIT (8) UNALIGNED INITIAL ('00000011'B),
2 FLGS BIT (16) UNALIGNED INITIAL ('0010000000000000'B),
2 DLNG BIT (32) UNALIGNED INITIAL (0),
2 BYTLIDT BIN FIXED (15) ALIGNED,
2 BYTLLTT BIN FIXED (15) ALIGNED,
2 IDTN3(0:511),
    3 IDTYPE BIN FIXED (15) ALIGNED INITIAL ((512)0),
    3 IDLNG BIN FIXED (15) ALIGNED INITIAL ((512)0),
    3 IDOFST BIN FIXED (15) ALIGNED INITIAL ((512)0);

DCL 1 WRTOBJT3 STATIC EXT,
2 DUMMY BIT (8) ALIGNED INITIAL (0),
2 OPCD BIT (8) UNALIGNED INITIAL ('00000011'B),
2 FLGS BIT (16) UNALIGNED INITIAL ('0010000000000000'B),
2 DLNG BIT (32) UNALIGNED INITIAL (0),
2 LTRLS CHAR (2000) ALIGNED INITIAL ('');


/* LOCAL VARIABLES */

DCL REPLY BIN FIXED (15) STATIC INITIAL (0);
DCL INPUTRM BIN FIXED (15) STATIC INIT (1);
DCL SICP BIN FIXED (15) STATIC INIT (0);
DCL PROCTN BIN FIXED (15) STATIC INIT (0);
DCL ALTRN8 BIN FIXED (15) STATIC INIT (0);
DCL RCNTR BIN FIXED STATIC INITIAL (0);
DCL TCNTR BIN FIXED STATIC INITIAL (0);
DCL IC1 BIN FIXED STATIC INITIAL (-1);
DCL IDNAME(0:255) CHAR(4) UNALIGNED STATIC EXT INIT ((256)(4)'');
DCL IDSTK(16) BIN FIXED (15) STATIC INITIAL ((16)0);
DCL IDSP BIN FIXED (15) STATIC INITIAL (0);
DCL LABEL BIN FIXED (15) STATIC INITIAL (0);
DCL (I,TEMP) BIN FIXED (15) STATIC;
DCL TEMP32 BIN FIXED (31) STATIC ;
DCL SROUT(80) LABEL ;
DCL ALT BIN FIXED (15) STATIC INITIAL (0);
DCL LTRNTKN(30) BIN FIXED (15) STATIC EXT INIT ((30)0);
DCL DFTYPE (90) BIN FIXED (15) STATIC EXT INIT
(+1,
-2,-2,
+3,
```

```
        +4,+4,
        +5,+5,
        +6,+6,
        +7,+7,
        +8,+8,+8,-8,-8,
        -9,
        +10,
        -11,-11.
        12,-12,
        +13,
        +14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,+14,
        +14,+14,
        +15,-15,+15,
        +16,+16,+16,
        -17,+17,
        -18,+18,
        -19,-19,
        -20,+20,
        -21,-21,-21,-21,-21,-21,
        -22,+22,
        -23,-23,-23,-23,-23,-23.-23,-23,
        +24,
        +25,-25,
        +26,+26,+26,+26,
        -27,-27,-27,-27,
        +28,+28,-28,+28,+28,-28,
        +29):
        DCL COMPRS(6) BIN FIXED (15) STATIC INITIAL
        (2232,2233,2235,2234,2230,2231);
        DCL HOLD(10) BIN FIXED STATIC INITIAL
        (0,0,0,4,0,0,0,0,0,0):
        REPLY = 0;
        TEMP = DFTYPE(COMPNT):
        LTRNTKN(ABS(TEMP)) = COMPNT:
        IF TEMP <= 0 THEN RETURN(0):
        IC1 = IC0:
        IF TEMP = 14 THEN GO TO SROUT(25):
        IF TEMP = 28 THEN GO TO SROUT(84):
        GO TO SROUT(COMPNT):
EXIT:
        IC0=IC1:
NOOP:
        RETURN(REPLY):
ERROR:
        REPLY = -3;
        IC0 = IC:
        IF RCNTR > 0 THEN RCNTR = 0:
        IF TCNTR > 0 THEN TCNTR = TCNTR-1:
        RETURN(REPLY):


 /* DEFINED TYPE 1                                                               */
 /*        1    GLUMP ::= FORM _I_                                              */

SROUT(1):
        CALL TABLES:
        DO I = 0 TO NMIDS:
```

```
        IF IDTYPE(I) = 0 THEN IDOFST(I) = 0;
        END;
        BYTLCDT = (IC+1)*2;
        WRTOBJI.DLNG = (8*BYTLCDT)+16;
        CALL SMFLIO(CMPLT3,WRTOBJI);
        BYTLLBT = 4*(NMLBS+1);
        WRTOBJT1.DLNG = (8*BYTLLBT)+16;
        CALL SMFLIO(CMPLT4,WRTOBJT1);
        BYTLIDT = 6*(NMIDS+1);
        TEMP32 = (8*BYTLIDT)+32;
        WRTOBJT2.DLNG = UNSPEC(TEMP32);
        CALL SMFSIO(CMPLT4,WRTOBJT2);
        BYTLLTT = LTEND+1;
        TEMP32 = 8*BYTLLTT;
        WRTOBJT3.DLNG = UNSPEC(TEMP32);
        CALL SMFSIO(CMPLT4,WRTOBJT3);
        GO TO EXIT;


 /* DEFINED TYPE 2                                                   */
 /*       2   FORM ::= RULE                                          */
 /*       3            | FORM RULE                                   */

        /* SROUT(2): */
        /* SROUT(3): */


 /* DEFINED TYPE 3                                                   */
 /*       4   RULE ::= LABEL INPUTSTREAM OUTPUTSTREAM :              */

SROUT(4):
        INPUTRM = 1;
        TCNTR = 0;
        CALL GNRTR(7000+RCNTR);
        RCNTR = RCNTR+1;
        TEMP = 3000+IC1+1;
        DO I = IC+1 TO IC1;
        IF CODE(I) = 2130 THEN CODE(I) = TEMP;
        END;
        ICO = I
        CALL SP[illegible]DE;
        LTRNTKN(4) = 0;
        LTRNTKN(5) = 0;
        LTRNTKN(6) = 0;
        GO TO EXIT;


 /* DEFINED TYPE 4                                                   */
 /*       5   LABEL ::= INTEGER                                      */
 /*       6            |                                             */

SROUT(5):
        HOLD(2) = BINARY(BCDVLU);
        TEMP = NMLBS;
        LABEL=FINDLB(HOLD(2));
        IF TEMP = NMLBS THEN
        DO;
```

```
        CALL DISPLAY(BCDVLU||' IS A DOUBLY DEFINED LABEL');
        GO TO ERROR;
        END;
        IF LABEL >= MXLBLS THEN GO TO ERROR;
        IF HOLD(2) < LBLFLR | HOLD(2) > LBLCLNG THEN
        DO;
        CALL DISPLAY(
        'LABEL'||BCDVLU||' IS NOT >='||LBLFLR||' OR <='||LBLCLNG);
        GO TO ERROR;
        END;

SROUT(6):
        IF INPUTRM = 1 THEN CALL GNRTR(2241);
        GO TO EXIT;


 /* DEFINED TYPE 5                                                     */
 /*       7    INPUTSTREAM ::= TERMS                                   */
 /*       8                      |                                     */

SROUT(7):
SROUT(8):
        GO TO SROUT(12);


 /* DEFINED TYPE 6                                                     */
 /*       9    TERMS ::= TERM                                          */
 /*      10              | TERMS , TERM                                */

SROUT(9):
SROUT(10):
        CALL GNRTR(6000+TCNTR);
        TCNTR = TCNTR+1;
        IDSP = 0;
        DO I = 7 TO VOCAB#-TERMINAL#;
        LTRNTKN(I)=0;
        END;
        DO I = 1 TO 10;
        HOLD(I) = 0;
        END;
        GO TO EXIT;


 /* DEFINED TYPE 7                                                     */
 /*      11    OUTPUTSTREAM ::= SEPERATOR TERMS                        */
 /*      12                       |                                    */

SROUT(11):
SROUT(12):
        INPUTRM = 0;
        GO TO EXIT;


 /* DEFINED TYPE 8                                                     */
 /*      13    TERM ::= IDENTIFIER ( DESCRIPTOR CONTROL )              */
 /*      14             | IDENTIFIER                                   */
 /*      15             | ( DESCRIPTOR CONTROL )                       */
```

```
 /*      16            | ( COMPAREXPR CONTROL )                         */
 /*      17            | ( ASSGNEXPR CONTROL )                          */

SROUT(13):
       GO TO SROUT(15);

SROUT(14):
       CALL GNRTR(5000);
       CALL GNRTR(IDSTK(1));
       CALL GNRTR(2112);
       CALL GNRTR(IDSTK(1));
       CALL GNRTR(IDSTK(1));
       CALL GNRTR(2111);
       IF INPUTRM = 0 THEN CALL GNRTR(2260);
       ELSE
       CALL GNRTR(2251);

SROUT(15):
       CALL GNRTR(2130);
       CALL GNRTR(2221);
       GO TO EXIT;

       /* SROUT(16): */
       /* SROUT(17): */


 /* DEFINED TYPE 9                                                      */
 /*      18    IDENTIFIEE ::= IDENTIFIER                                */

       /* SROUT(18): */


 /* DEFINED TYPE 10                                                     */
 /*      19    DESCRIPTOR ::= REP , DATYPE , VALUE , LENGTH             */

SROUT(19):
       IF INPUTRM = 0 THEN CALL GNRTR(2260);
       ELSE
       DO;
       IF LTRNTKN(9) = 0 THEN CALL GNRTR(2251);
       ELSE
       DO;
       CALL GNRTR(2250);
       CALL GNRTR(3000+(IC1*4)+1);
       CALL GNRTR(2221);
       CALL GNRTR(IDSTK(1));
       CALL GNRTR(2200);
       END;
       END;
       GO TO EXIT;


 /* DEFINED TYPE 11                                                     */
 /*      20    CONTROL ::= : OPTIONS                                    */
 /*      21                |                                            */

       /* SROUT(20): */
```

```
      /* SROUT(21): */


 /* DEFINED TYPE 12                                                    */
 /*      22   COMPAREEXPR ::= CONCAT CONNECTIVE CONCAT                 */
 /*      23                 |                                          */

SROUT(22):
      CALL GNRTR(COMPRS(LTRNTKN(21)-56));
      GO TO EXIT;

      /* SROUT(23): */


 /* DEFINED TYPE 13                                                    */
 /*      24   ASSGNEXPR ::= IDENTIFIER .<=. CONCAT                     */

SROUT(24):
      CALL GNRTR(IDSTK(1));
      CALL GNRTR(2200);
      GO TO EXIT;


 /* DEFINED TYPE 14                                                    */
 /*      25   IDENTIFIER ::= A                                         */
 /*      26                | B                                         */
 /*      27                | E                                         */
 /*      28                | F                                         */
 /*      29                | L                                         */
 /*      30                | O                                         */
 /*      31                | S                                         */
 /*      32                | T                                         */
 /*      33                | U                                         */
 /*      34                | V                                         */
 /*      35                | X                                         */
 /*      36                | AE                                        */
 /*      37                | ED                                        */
 /*      38                | ER                                        */
 /*      39                | SB                                        */
 /*      40                | SR                                        */
 /*      41                | UR                                        */
 /*      42                | <ALPHA ALPHANUM>                          */

SROUT(25):
      /* SROUT(26): */
      /* SROUT(27): */
      /* SROUT(28): */
      /* SROUT(29): */
      /* SROUT(30): */
      /* SROUT(31): */
      /* SROUT(32): */
      /* SROUT(33): */
      /* SROUT(34): */
      /* SROUT(35): */
      /* SROUT(36): */
      /* SROUT(37): */
      /* SROUT(38): */
```

```
      /* SROUT(39): */
      /* SROUT(40): *
      /* SROUT(41): */
      /* SROUT(42): */
      TEMP = LENGTH(BCDVLU);
      IF TEMP > IDLNGTH THEN
      DO;
      CALL DISPLAY('IDENTIFIER:');
      CALL DISPLAY(BCDVLU);
      CALL DISPLAY(
      'HAS'||TEMP||' CHARACTERS. MAX IS 4');
      GO TO ERROR;
      END;
      IDSP = IDSP+1;
      IF IDSP > MXSTKSZ THEN
      DO;
      CALL DISPLAY('IDSTACK OVERFLOW. MAX IS'||MXSTKSZ);
      IDSP = 0;
      GO TO ERROR;
      END;
      IDSTK(IDSP) = FINDID(BCDVLU);
      IF IDSTK(IDSP) >= MXIDS THEN GO TO ERROR;
      IF IDOFST(IDSTK(IDSP)) >= MXNDXS THEN GO TO ERROR;
      GO TO EXIT;


 /* DEFINED TYPE 15                                                  */
 /*      43   REP ::= #                                              */
 /*      44           | ARITH                                        */
 /*      45           |                                              */

SROUT(43):
      CALL GNRTR(4000);
      GO TO EXIT;

      /* SROUT(44): */

SROUT(45):
      CALL GNRTR(5000);
      GO TO EXIT;


 /* DEFINED TYPE 16                                                  */
 /*      46   DATYPE ::= LITYPE                                      */
 /*      47              | T ( IDENTIFIER )                          */
 /*      48              |                                           */

SROUT(46):
      CALL GNRTR(1000+LTRNTKN(23)-64);
      GO TO EXIT;

SROUT(47):
      CALL GNRTR(IDSTK(IDSP));
      CALL GNRTR(2112);
      GO TO EXIT;

SROUT(48):
```

```
      LTRNTKN(23) = 65;
      GO TO SROUT(46);


 /* DEFINED TYPE 17                                              */
 /*      49    VALUE ::= CONCAT                                  */
 /*      50              |                                       */

      /* SROUT(49): */

SROUT(50):
      CALL GNRTR(5000);
      GO TO EXIT;


 /* DEFINED TYPE 18                                              */
 /*      51    LENGTH ::= ARITH                                  */
 /*      52               |                                      */

      /* SROUT(51): */

SROUT(52):
      IF LTRNTKN(16) = 48 THEN CALL GNRTR(1032);
      GO TO EXIT;


 /* DEFINED TYPE 19                                              */
 /*      53    OPTIONS ::= TEST                                  */
 /*      54                | TEST , TEST                         */

      /* SROUT(53): */
      /* SROUT(54): */


 /* DEFINED TYPE 20                                              */
 /*      55    CONCAT ::= VAL                                    */
 /*      56               | CONCAT || VAL                        */

      /* SROUT(55): */

SROUT(56):
      CALL GNRTR(2040);
      GO TO EXIT;


 /* DEFINED TYPE 21                                              */
 /*      57    CONNECTIVE ::= .LE.                               */
 /*      58                   | .LT.                             */
 /*      59                   | .GE.                             */
 /*      60                   | .GT.                             */
 /*      61                   | .EQ.                             */
 /*      62                   | .NE.                             */

      /* SROUT(57): */
      /* SROUT(58): */
      /* SROUT(59): */
      /* SROUT(60): */
```

```
      /* SROUT(61): */
      /* SROUT(62): */


 /* DEFINED TYPE 22                                                    */
 /*      63   ARITH ::= PRIMARY                                        */
 /*      64             | ARITH OPERATOR PRIMARY                       */

      /* SROUT(63): */

SROUT(64):
      CALL GNRTR(2000+(LTRNTKN(27)-80)*10);
      GO TO EXIT;


 /* DEFINED TYPE 23                                                    */
 /*      65   LITYPE ::= B                                             */
 /*      66              | O                                           */
 /*      67              | X                                           */
 /*      68              | E                                           */
 /*      69              | A                                           */
 /*      70              | ED                                          */
 /*      71              | AD                                          */
 /*      72              | SB                                          */

      /* SROUT(65): */
      /* SROUT(66): */
      /* SROUT(67): */
      /* SROUT(68): */
      /* SROUT(69): */
      /* SROUT(70): */
      /* SROUT(71): */
      /* SROUT(72): */


 /* DEFINED TYPE 24                                                    */
 /*      73   TEST ::= <SFUR IDENT> ( ARITH )                          */

SROUT(73):
      IF LTRNTKN(28) >= 87 THEN CALL GNRTR(2210);
      ELSE
      DO;
      CALL GNRTR(2120);
      CALL GNRTR(2222);
      END;
      IF LTRNTKN(28) ¬= 86 & LTRNTKN(28) ¬= 89 THEN
      CODE(ALT) = 3000+IC1+1;
      GO TO EXIT;


 /* DEFINED TYPE 25                                                    */
 /*      74   VAL ::= LITYPE LITSTRING                                 */
 /*      75           | ARITH                                          */

SROUT(74):
      TEMP = FINDLT(BCDVLU,LTRNTKN(23)-64);
      IF TEMP < 0 THEN GO TO ERROR;
```

```
       CALL GNRTR(TEMP);
       GO TO EXIT;


  /* DEFINED TYPE 26                                                   */
  /*       76    PRIMARY ::= IDENTIFIER                                */
  /*       77                | L ( IDENTIFIER )                        */
  /*       78                | V ( IDENTIFIER )                        */
  /*       79                | INTEGER                                 */

       /* SROUT(75): */

SROUT(76):
       CALL GNRTR(IDSTK(IDSP));
       GO TO EXIT;

SROUT(77):
       CALL GNRTR(IDSTK(IDSP));
       CALL GNRTR(2111);
       GO TO EXIT;

SROUT(78):
       CALL GNRTR(IDSTK(IDSP));
       CALL GNRTR(2110);
       GO TO EXIT;

SROUT(79):
       HOLD(1) = BINARY(BCDVLU);
       CALL GNRTR(1000+HOLD(1));
       GO TO EXIT;


  /* DEFINED TYPE 27                                                   */
  /*       80    OPERATOR ::= +                                        */
  /*       81                 | -                                      */
  /*       82                 | *                                      */
  /*       83                 | /                                      */

       /* SROUT(80): */
       /* SROUT(81): */
       /* SROUT(82): */
       /* SROUT(83): */


  /* DEFINED TYPE 28                                                   */
  /*       84    <SFUR IDENT> ::= S                                    */
  /*       85                   | F                                    */
  /*       86                   | U                                    */
  /*       87                   | SR                                   */
  /*       88                   | FR                                   */
  /*       89                   | UR                                   */

SROUT(84):
       /* SROUT(85): */
       /* SROUT(86): */
       /* SROUT(87): */
       /* SROUT(88): */
```

```
      /* SROUT(89): */
      ALT = IC1+1;
      CALL GNRTR(2130);
      IF LTRNTKN(28) = 84 | LTRNTKN(28) = 87 THEN CALL GNRTR(2221);
      IF LTRNTKN(28) = 85 | LTRNTKN(28) = 88 THEN CALL GNRTR(2220);
      GO TO EXIT;


 /* DEFINED TYPE 29                                                    */
 /*     90    SEPERATOR ::= :                                          */

SROUT(90):
      CALL GNRTR(2240);
      GO TO EXIT;



GNRTR: PROCEDURE(INSTRCTN) RETURNS(BIN FIXED (15));
      DCL INSTRCTN BIN FIXED (15);
      DCL SAID BIN FIXED (15) ALIGNED STATIC INITIAL (0);

      /* ROUTINE TO POST AN INSTRUCTION */

      I = IC1+1;
      IF I >= MXINSTS THEN
      DO;
      IF SAID = 0 THEN
      CALL DISPLAY(
      'INSTRUCTION STACK OVERFLOW. MAX IS '||MXINSTS);
      SAID = 1;
      REPLY = -3;
      I = IC;
      RETURN;
      END;
      IC1 = I;
      CODE(IC1) = INSTRCTN;
      END GNRTR;



FINDLB: PROCEDURE(L) RETURNS(BIN FIXED (15));
         DCL L BIN FIXED  (15);
         DCL SAID BIN FIXED (15) ALIGNED STATIC INITIAL (0);

         /* ROUTINE TO FIND A LABEL */

         IF  NMLBS >= 0 THEN
         DO I = 0 TO NMLBS;
         IF LBLVLU(I) = L THEN RETURN(I);
         END;
         I = NMLBS+1;
         IF I >= MXLBLS THEN
         DO;
         IF SAID = 0 THEN
         CALL DISPLAY('LABEL TABLE OVERFLOW. MAX IS '||MXLBLS);
         LBLOFST(NMLBS) = (IC+1)*2;
         SAID = 1;
```

```
         REPLY = -3;
         RETURN(MXLBLS);
         END;
         NMLBS = I;
         LBLVLU(NMLBS) = L;
         RETURN(NMLBS);
         END FINDLB;



FINDID:PROCEDURE(K) RETURNS(BINARY FIXED (15));
         DCL K CHAR(4) VAR ;
         DCL SAID BIN FIXED (15) ALIGNED STATIC INITIAL (0);
         DCL SAID2 BIN FIXED (15) ALIGNED STATIC INITIAL (0);

         /* ROUTINE TO FIND AN IDENTIFIER */

         IF NMNDXS >= 0 THEN
         DO I = 0 TO NMIDS;
         IF IDTYPE(I) = 0 THEN
         DO;
         IF IDNAME(IDOFST(I)) = K THEN RETURN(I);
         END;
         END;
         I = NMNDXS+1;
         IF NMNDXS >= MXNDXS THEN
         DO;
         IF SAID = 0 THEN
         CALL DISPLAY(
         'EXCEEDED MAX NUMBER OF IDENTIFIERS. MAX IS'||MXNDXS);
         SAID = 1;
         REPLY = -3;
         I = MXNDXS;
         END;
         NMNDXS = I;
         IDNAME(NMNDXS) = K;

GETIDNT: ENTRY RETURNS (BIN FIXED (15));
         I = NMIDS+1;
         IF I >= MXIDS THEN
         DO;
         IF SAID2 = 0 THEN
         CALL DISPLAY('IDENTIFIER TABLE OVERFLOW. MAX IS'||MXNDXS);
         SAID2 = 1;
         REPLY = -3;
         RETURN(MXIDS);
         END;
         NMIDS = I;
         IDOFST(NMIDS) = NMNDXS;
         IDTYPE(NMIDS) = 0.
         RETURN(NMIDS);
         END FINDID;



FINDLT: PROCEDURE(M,N) RETURNS(BIN FIXED (15));
         DCL M CHAR(256) VAR ;
```

```
DCL N BIN FIXED (15);
DCL (POS,J,INDX,TMPNMIDS) BIN FIXED (15) STATIC;
DCL NMBR BIN FIXED (31) STATIC INITIAL (0);
DCL TBITSTR BIT (8) UNALIGNED STATIC INITIAL ('0'B);
DCL CHR1 CHAR(1) STATIC;
DCL CHR4 CHAR(4) STATIC;
DCL SAID BIN FIXED ALIGNED STATIC INITIAL (0);
DCL LNGTH(0:8) BIN FIXED (15) STATIC ALIGNED INITIAL (
0,2,8,16,79,79,10,10,2);
DCL TRNSL8R(1:2,0:78) BIT (8) UNALIGNED STATIC EXT INITIAL (
'11110000'B,
'11110001'B,
'11110010'B,
'11110011'B,
'11110100'B,
'11110101'B,
'11110110'B,
'11110111'B,
'11111000'B,
'11111001'B,
'11000001'B,
'11000010'B,
'11000011'B,
'11000100'B,
'11000101'B,
'11000110'B,
'11000111'B,
'11001000'B,
'11001001'B,
'11010001'B,
'11010010'B,
'11010011'B,
'11010100'B,
'11010101'B,
'11010110'B,
'11010111'B,
'11011000'B,
'11011001'B,
'11100010'B,
'11100011'B,
'11100100'B,
'11100101'B,
'11100110'B,
'11100111'B,
'11101000'B,
'11101001'B,
'01000000'B,
'01001011'B,
'01001101'B,
'01001110'B,
'01010000'B,
'01011011'B,
'01011100'B,
'01011101'B,
'01100000'B,
'01100001'B,
'01101011'B,
```

```
'01101100'B,
'01111011'B,
'01111100'B,
'01111101'B,
'01111110'B,
'10000001'B,
'10000010'B,
'10000011'B,
'10000100'B,
'10000101'B,
'10000110'B,
'10000111'B,
'10001000'B,
'10001001'B,
'10010001'B,
'10010010'B,
'10010011'B,
'10010100'B,
'10010101'B,
'10010110'B,
'10010111'B,
'10011000'B,
'10011001'B,
'10100010'B,
'10100011'B,
'10100100'B,
'10100101'B,
'10100110'B,
'10100111'B,
'10101000'B,
'10101001'B,
'00000000'B,
'01010000'B,
'01010001'B,
'01010010'B,
'01010011'B,
'01010100'B,
'01010101'B,
'01010110'B,
'01010111'B.
'01011000'B,
'01011001'B,
'10100001'B,
'10100010'B,
'10100011'B,
'10100100'B,
'10100101'B,
'10100110'B,
'10100111'B,
'10101000'B,
'10101001'B,
'10101010'B,
'10101011'B,
'10101100'B,
'10101101'B,
'10101110'B,
'10101111'B.
```

```
'10110000'B,
'10110001'B,
'10110010'B,
'10110011'B,
'10110100'B,
'10110101'B,
'10110110'B,
'10110111'B,
'10111000'B,
'10111001'B,
'10111010'B,
'01000000'B,
'01001110'B,
'01001000'B,
'01001011'B,
'01000110'B,
'01000100'B,
'01001010'B,
'01001001'B,
'01001101'B,
'01001111'B,
'01001100'B,
'01000101'B,
'01000011'B,
'10100000'B,
'01000111'B,
'01011101'B,
'11100001'B,
'11100010'B,
'11100011'B,
'11100100'B,
'11100101'B,
'11100110'B,
'11100111'B,
'11101000'B,
'11101001'B,
'11101010'B,
'11101011'B,
'11101100'B,
'11101101'B,
'11101110'B,
'11101111'B,
'11110000'B,
'11110001'B,
'11110010'B,
'11110011'B,
'11110100'B,
'11110101'B,
'11110110'B,
'11110111'B,
'11111000'B,
'11111001'B,
'11111010'B,
'00000000'B);

/* ROUTINE TO FIND A LITERAL */
```

```
        NMBR = 0;
        REPLY = -3;
        TMPNMIDS = GETIDNT;
        IF TMPNMIDS >= MXIDS THEN RETURN(-1);
        NMIDS = NMIDS-1;
        IDTYPE(TMPNMIDS) = N;
        IDLNG(TMPNMIDS) = LENGTH(M);
        IF IDTYPE(TMPNMIDS) = 0 | IDLNG(TMPNMIDS) = 0 THEN RETURN(-1);
        IF (LTEND+IDLNG(TMPNMIDS) > MXLITS &
        ( N > 3 | N < 6)) | (LTEND+4 > MXLITS &
        ( N <= 3 | N >= 6)) THEN
        DO;
        IF SAID = 0 THEN
        CALL DISPLAY(
        'LITERAL TABLE OVERFLOW. MAX IS'||MXLITS||' BYTES.');
        SAID = 1;
        RETURN(-1);
        END;
        IDOFST(TMPNMIDS) = LTEND;
        IF N = 5 THEN INDX = 2; ELSE INDX = 1;
        DO POS = 1 TO IDLNG(TMPNMIDS);
        TBITSTR = UNSPEC(SUBSTR(M,POS,1));
        DO J = 0 TO 78;
        IF TBITSTR = TRNSLBR(1,J) THEN GO TO GUUD;
        END;
ERROR:
        CALL DISPLAY('LITERAL:');
        CALL DISPLAY(M);
        CALL DISPLAY('IS NOT IN ITS SPECIFIED MODE');
        RETURN(-1);
GUUD:
        IF J >= LNGTH(N) THEN GO TO ERROR;
        IF N <= 3 | N >= 6 THEN NMBR = J+LNGTH(N)*NMBR;
        ELSE
        DO;
        UNSPEC(CHR1) = TRNSLBR(INDX,J);
        SUBSTR(LTRLS,LTEND+POS,1) = CHR1;
        END;
        END;
        REPLY = 0;
        IF N <= 3  | N>= 6 THEN
        DO;
        IF N = 8 THEN NMBR = -NMBR;
        IDLNG(TMPNMIDS) = 4;
        UNSPEC(CHR4) = UNSPEC(NMBR);
        SUBSTR(LTRLS,LTEND+1,4) = CHR4;
        END;
        DO POS = 0 TO NMIDS;
        IF IDTYPE(POS) = IDTYPE(TMPNMIDS) &
        IDLNG(POS) = IDLNG(TMPNMIDS)*8 &
        SUBSTR(LTRLS,IDOFST(POS)+1,IDLNG(POS)/8) =
        SUBSTR(LTRLS,IDOFST(TMPNMIDS)+1,IDLNG(TMPNMIDS))
        THEN RETURN(POS);
        END;
        NMIDS = TMPNMIDS;
        LTEND = IDOFST(TMPNMIDS)+IDLNG(TMPNMIDS);
        IF N > 3 & N < 6 THEN
```

```
      LTEND = TRUNC((LTEND+3)/4)*4;
          IDLNG(TMPNMIDS) = IDLNG(TMPNMIDS)*8;
          RETURN(TMPNMIDS);
          END FINDLT;



PUCODE: PROCEDURE;
      DCL (I,J,K,L) BIN FIXED (15) STATIC;
      DCL TEXT CHAR(72) STATIC INITIAL ('');
      DCL SYMBOL CHAR(4) STATIC INITIAL ('');
      DCL OPRTRS(64) CHAR (4) STATIC EXT INIT
      ('LD','IC','','AD','ARB','NULL','FOT','FOR','ADD','SUB','MUL',
      'DIV','CON','','','','LIV','LIL','LIT','LUL','','','STO','','',
      '','','','RET','','','','','','BT','BF','BU','','','','CEQ',
      'CNE','CLE','CLT','CGE','CGT','SCIP','SICP','','','','',
      'INS','IND','','','','','OUT','','','','','');
      DECLARE BYTE(4) BIN FIXED STATIC ;
      DCL OPRTR CHAR(4) STATIC;
      DCL OPRND BIN FIXED STATIC;

      /* ROUTINE TO REFORMAT AND LIST INSTRUCTIONS OF A RULE */

      CALL DISPLAY(' ');
      CALL DISPLAY(' ISN    INSTRCT    OPCD  OPRND  SYMBOL');
      DO I=1 TO ICO-IC;
      IC = IC+1;
      K = CODE(IC);
      DO J = 1 TO 4;
      L = K/10;
      BYTE(5-J) = K-L*10;
      K = L;
      END;
      OPRTR = OPRTRS(BYTE(1)+1);
      IF BYTE(1) = 2 | BYTE(1) = 4 | BYTE(1) = 5 THEN
      DO;
      K = 0;
      DO J = 1 TO 4;
      K = BYTE(J)+K*16;
      END;
      CODE(IC) = K;
      IF BYTE(1) = 2 THEN
      DO;
      OPRTR = OPRTRS(9+BYTE(3));
      IF BYTE(2) ¬= 0 THEN
      DO;
      OPRTR = OPRTRS(14+BYTE(3)*3+BYTE(4));
      IF BYTE(2) ¬= 1 THEN
      DO;
      OPRTR = OPRTRS(23+BYTE(3)*6+BYTE(4));
      END;
      END;
      END;
      PUT STRING(TEXT) EDIT(IC,BYTE(1),BYTE(2),BYTE(3),BYTE(4),OPRTR)
      (F(4),X(4),F(1),X(1),F(1),X(1),F(1),X(1),F(1),X(4),A(4));
      END;
      ELSE
```

```
      DO;
      OPRND = BYTE(2)*100+BYTE(3)*10+BYTE(4);
      CODE(IC) = 4096*BYTE(1)+OPRND;
      SYMBOL = ' ';
      IF BYTE(1) = 0 THEN
      DO;
      IF IDTYPE(OPRND) = 0 THEN
      SYMBOL = IDNAME(IDOFST(OPRND));
      END;
      PUT STRING(TEXT) EDIT (IC,BYTE(1),OPRND,OPRTR,OPRND,SYMBOL)
      (F(4),X(4),F(1),X(2),F(4),X(4),A(4),X(2),F(4),X(2),A(4));
      END;
      CALL DISPLAY(TEXT);
      END;
      CALL DISPLAY(' ');
      END SPUCODE;



TABLES: PROCEDURE;
      DCL LN BIN FIXED STATIC INITIAL (0);
      DCL VAL CHAR (6) VAR STATIC INITIAL ('');
      DCL VALU BIT (48) ALIGNED STATIC INITIAL ('0'B);
      DCL TEXT CHAR (72) VAR ALIGNED STATIC INITIAL ('');
      DCL TPNAME(0:8) CHAR (2) UNALIGNED STATIC INITIAL (
      ' U',' B',' O',' X',' E',' A','FD','AD','SB');

      /* ROUTINE TO LIST THE CONTENT OF THE COMPILER TABLES */


      CALL DISPLAY(' ');
      CALL DISPLAY(' ');
      CALL DISPLAY('****** LABEL TABLE ******');
      CALL DISPLAY(' ');
      IF NMLBS < 0 THEN CALL DISPLAY('NO LABELS DECLARED');
      ELSE
      DO;
      CALL DISPLAY('ENTRY      LABEL     OFFSET');
      CALL DISPLAY(' ');
      DO I = 0 TO NMLBS;
      PUT STRING(TEXT) EDIT (I,LB VLU(I),LBLOFST(I))
      (F(5),X(5),F(5),X(4),F(6));
      CALL DISPLAY(TEXT);
      END;
      END;
      CALL DISPLAY(' ');
      CALL DISPLAY('****** IDENTIFIER TABLE ******');
      CALL DISPLAY(' ');
      IF NMNDXS < 0 THEN CALL DISPLAY('NO IDENTIFIERS DECLARED');
      ELSE
      DO;
      CALL DISPLAY('ENTRY                   IDENTIFIER');
      CALL DISPLAY(' ');
      DO I = 0 TO NMIDS;
      IF IDTYPE(I) = 0 THEN
      DO;
      PUT STRING(TEXT) EDIT (I,IDNAME(IDOFST(I)))
```

```
(F(5),X(18),A(4));
CALL DISPLAY(TEXT);
END;
END;
END;
CALL DISPLAY(' ');
CALL DISPLAY('*******    LITERAL TABLE    *******');
CALL DISPLAY(' ');
IF LTEND = 0 THEN CALL DISPLAY('NO LITERALS DECLARED');
ELSE
DO;
CALL DISPLAY('ENTRY TYPE LENGTH OFFSET  LITERAL');
CALL DISPLAY(' ');
DO I = 0 TO NMIDS;
IF IDTYPE(I) ¬= 0 THEN
DO;
VALU = '0'B;
VAL = SUBSTR(LTRLS,IDOFST(I)+1,IDLNG(I)/8);
IF IDLNG(I) > 48 THEN LN = 48; ELSE LN = IDLNG(I);
VALU = UNSPEC(VAL);
PUT STRING(TEXT) EDIT (I,TPNAME(IDTYPE(I)),IDLNG(I),IDOFST(I),VALU
)
(F(5),X(1),A(2),X(1),F(5),X(1),F(6),X(2),B(LN));
CALL DISPLAY(TEXT);
END;
END;
END;
END TABLES;
END SMNTC;
```

```
SMESIO: PROCEDURE(DS,STRUCT):


      /*  SHARED VARIABLES */

      DCL TRACE BIN FIXED (31) STATIC EXT:
      DCL LINESZ BIN FIXED (15) STATIC EXT INITIAL (72):
      DCL LINE CHAR (332) VAR ALIGNED STATIC EXT INITIAL (''):
      DCL INPUT CHAR (84) VAR ALIGNED STATIC EXT INITIAL (''):



      /* ROUTINES INVOKED BY SMESIO  AND ENTRY POINTS */

      DCL DSPLAY ENTRY (CHAR (72) VAR):
      DCL @WRITE ENTRY (BIN FIXED (31), (0:1) BIN FIXED (31),
      BIN FIXED (31), BIN FIXED (31)):
      DCL @READ ENTRY (BIN FIXED (31), (0:1) BIN FIXED (31),
      BIN FIXED (31), BIN FIXED (31)):
      DCL @OPEN ENTRY (BIN FIXED (31), BIN FIXED (31),
      (2) BIN FIXED (31), (2) BIN FIXED (31), (2) BIN FIXED (31)):
      DCL @CLOSE ENTRY (BIN FIXED (31), BIN FIXED (31));
      DCL POINT ENTRY:


      /* VARIABLES FOR SMES */

      DCL 1 WRTOBJT STATIC EXT,
      2 OPCD BIT (8) UNALIGNED INITIAL ('00000011'B),
      2 FLGS BIT (16) UNALIGNED INITIAL ('0010000000000000'B),
      2 DLNG BIT (32) UNALIGNED INITIAL (0):

      DCL 1 STRUCT ALIGNED,
      2 DUMMY BIT (8) ALIGNED,
      2 OPCD BIT(8) UNALIGNED,
      2 FLGS BIT(16) UNALIGNED,
      2 DLNG BIT(32) UNALIGNED,
      2 DATA BIN FIXED (15) ALIGNED:

      DCL 1 STRCT UNALIGNED,
      2 OPCD BIT(8) UNALIGNED,
      2 FLGS BIT(16) UNALIGNED,
      2 NLNG BIT(8) UNALIGNED,
      2 FNAM CHAR (36) UNALIGNED,
      2 FLNG BIN FIXED (31) ALIGNED:

      DCL 1 WRTDIAG STATIC UNALIGNED EXT,
      2 OPCD BIT (8) INITIAL ('00000011'B),
      2 FLGS BIT (16) INITIAL ('0010000001000000'B),
      2 DLNG BIT (32) INITIAL ('00000000000000000000001001000000'B),
      2 DATA CHAR (72) INITIAL (''):

      DCL 1 GTSRCE STATIC  EXT,
      2 OPCD BIT(8) UNALIGNED INITIAL ('00000101'B).
      2 FLGS BIT(16) UNALIGNED INITIAL ('0010000000000000'B),
      2 DLNG BIT(32) UNALIGNED INIT
      ('00000000000000000000000101000000'B):
```

```
        DCL WRKSPS1(2) BIN FIXED (31) ALIGNED STATIC EXT;
        DCL CMPLT1(2) BIN FIXED (31) ALIGNED STATIC EXT;
        DCL CMPLT2(2) BIN FIXED (31) ALIGNED STATIC EXT;
        DCL SOKT BIN FIXED (31);
        DCL SSKT(2) BIN FIXED (31) STATIC INIT (3,0);
        DCL RSKT(2) BIN FIXED (31) STATIC INIT (3,0);
        DCL LTIME28 BIN FIXED (31) STATIC INITIAL (10000);
        DCL STIME28 BIN FIXED (31) STATIC INITIAL (300);



        /* LOCAL VARIABLES */

        DCL WS(2) BIN FIXED (31);
        DCL DS(2) BIN FIXED (31);
        DCL LEN BIN FIXED (31) STATIC INIT (0);
        DCL OPCODE BIN FIXED (15) STATIC INITIAL (0);
        DCL NODIAGFL BIN FIXED (15) STATIC INITIAL (0);
        DCL TEXT CHAR (72) VAR;
        DCL AFR(0:1) BIN FIXED (31) STATIC EXT INIT ((2)0);
        DCL BFR(0:1) BIN FIXED (31) STATIC EXT;



        OPCODE = WRTOBJT.OPCD;
        WRTOBJT.DLNG = STRUCT.DLNG;
        LEN = WRTOBJT.DLNG;
        IF TRACE = 1 THEN CALL DSPLAY(
        'SMFS OPCODE:'||OPCODE||' LENGTH OF DATA:'||LEN);
        CALL POINT(BFR,ADDR(WRTOBJT.OPCD));
        CALL @WRITE(DS(1),BFR,56,LTIME28);
        IF DS(1) > 0 THEN GO TO REPORT;
        CALL POINT(BFR,ADDR(STRUCT.DATA));
        CALL @WRITE(DS(1),BFR,LEN,LTIME28);
COMMON:
        IF DS(1) > 0 THEN GO TO REPORT;
        CALL @READ(DS(2),AFR,8,LTIME28);
        IF DS(2) > 0 THEN GO TO REPORT;
        AFR(1) = AFR(0)/(256**3);
        IF AFR(1) < 2 | AFR(1) > 8 THEN
        DO;
        CALL DSPLAY(
        'NO I/O: SMFS REPORTS COMPLETION CODE '||AFR(1));
        END;
        RETURN;



SMFLIO: ENTRY(DS,STRCT);
        OPCODE = STRCT.OPCD;
        LEN = 0;
        IF OPCODE = 3 THEN
        LEN = STRCT.FLNG;
        LEN = LEN+352;
        CALL POINT(BFR,ADDR(STRCT.OPCD));
        CALL @WRITE(DS(1),BFR,LEN,LTIME28);
```

```
        LEN = LEN-352;
        GO TO COMMON;



SMFOIO: ENTRY(DS,SOKT,WS);
        SSKT(2) = SOKT;
        RSKT(2) = 1025;
        CALL @OPEN(DS(1),STIME28,SSKT,RSKT,WS);
        IF DS(1) = 0 THEN
        DO;
        CALL @READ(DS(1),AFR,32,LTIME28);
        IF DS(1) = 0 THEN
        DO;
        CALL @CLOSE(DS(1),STIME28);
        SSKT(2) = SOKT+2;
        RSKT(2) = AFR(1)+1;
        CALL @OPEN(DS(2),STIME28,SSKT,RSKT,WS);
        IF DS(2) = 0 THEN
        DO;
        SSKT(2) = SOKT+3;
        RSKT(2) = AFR(0);
        CALL @OPEN(DS(1),STIME28,SSKT,RSKT,WS);
        IF DS(1) = 0 THEN RETURN;
        END;
        END;
        END;
        CALL DSPLAY(
        'SEND SOCKET:'||SOKT+3);
        CALL DSPLAY(
        'RECEIVE SOCKET:'||SOKT+2);
        CALL DSPLAY(
        'NO OPEN');
        GO TO REPRT;
REPORT:
        CALL DSPLAY(
        'NO INPUT/OUTPUT');
REPRT:
        CALL DSPLAY(
        'NCP REPORTS COMPLETION CODE '||DS(1)||' ON SEND SOCKET');
        CALL DSPLAY(
        'NCP REPORTS COMPLETION CODE '||DS(2)||' ON RECEIVE SOCKET');
        RETURN;



SMFCIO: ENTRY(DS);
        CALL @CLOSE(DS(1),STIME28);
        CALL @CLOSE(DS(2),STIME28);
        RETURN;



DISPLAY: ENTRY(TEXT);
        CALL DSPLAY(TEXT);
        RETURN;

```

```
READ: ENTRY RETURNS(BIN FIXED (15));
      IF CMPLT1(2) = 20 THEN RETURN(0):
      CALL POINT(BFR,ADDR(GTSRCE.OPCD)):
      LEN = 56+GTSRCE.DLNG;
      CALL @WRITE(CMPLT1(1),BFR,LEN,LTIME28):
      IF CMPLT1(1) > 0 THEN GO TO NOINPT:
      CALL @READ(CMPLT1(2),AFR,8,LTIME28):
      IF CMPLT1(2) > 0 THEN GO TO NOINPT:
      AFR(1) = AFR(0)/(256**3):
      IF AFR(1) ¬= 5 THEN
      DO:
      CALL DSPLAY(
      'NO INPUT.  SMFS REPORTS COMPLETION CODE:'||AFR(1));
      IF AFR(1) = 42 | AFR(1) = 22 | AFR(1) = 23 | AFR(1) = 32 |
      AFR(1) = 33 | AFR(1) = 34 | AFR(1) = 39 THEN
      RETURN(0):
      END;
      CALL @READ(CMPLT1(2),AFR,32,LTIME28):
      IF CMPLT1(2) > 0 THEN GO TO NOINPT:
      LEN = AFR(0):
      IF LEN > 0 THEN
      DO:
      CALL POINT(BFR,ADDR(INPUT)):
      CALL @READ(CMPLT1(2),BFR,LEN,LTIME28):
      IF CMPLT1(2) > 0 THEN GO TO NOINPT:
      END:
      ELSE
      DO;
      IF LEN = 0 THEN RETURN(0):
NOINPT:
      IF TRACE = 1 THEN
      DO:
      CALL DSPLAY(
      'NO INPUT'):
      CALL DSPLAY(
      'NCP REPORTS COMPLETION CODE '||CMPLT1(1)||' ON SEND SOCKET'):
      CALL DSPLAY(
      'NCP REPORTS COMPLETION CODE '||CMPLT1(2)||' ON RECEIVE SOCKET'):
      END;
      RETURN(0);
      END:
      RETURN(LEN/8);



POINT: PROCEDURE(I,J):
      DCL (I,J) POINTER;
      I = J;
      END POINT;



DSPLAY: PROCEDURE(TXT):
      DCL TXT CHAR (72) VAR;
      WRTDIAG.DATA = TXT;
```

```
CALL POINT(BFR,ADDR(WRTDIAG.OPCD));
IF NODIAGFL = 0 THEN
DO;
LEN = 56+WRTDIAG.DLNG;
CALL @WRITE(CMPLT2(1),BFR,LEN,LTIME28);
IF CMPLT2(1) = 0 THEN
DO;
CALL @READ(CMPLT2(2),AFR,8,LTIME28);
IF CMPLT2(2) = 0 THEN
DO;
AFR(1) = AFR(0)/(256**3);
IF AFR(1) = 3 THEN RETURN;
END;
END;
IF NODIAGFL = 0 THEN
DO;
PUT SKIP LIST (
'UNABLE TO USE DIAGNOSTIC FILE. OUTPUT DIVERTED TO SYSPRINT');
PUT SKIP LIST(
'SMFS REPORTS COMPLETION CODE:',AFR(1));
PUT SKIP LIST(
'NCP REPORTS COMPLETION CODE:',CMPLT2(1),' ON SEND SOCKET');
PUT SKIP LIST(
'NCP REPORTS COMPLETION CODE:',CMPLT2(2),' ON RECEIVE SOCKET');
NODIAGFL = 1;
END;
END;
PUT SKIP LIST(WRTDIAG.DATA);
RETURN;
END DSPLAY;
END SMFSIO;
```

```
@OPEN: PROCEDURE(CMPCD,TIME,LCLSCK,FGNSCK,WS);


      /* SHARED VARIABLES */

      DCL TRACE BIN FIXED (31) STATIC EXT;
      DCL WRKSPS1(2) BIN FIXED (31) ALIGNED STATIC EXT;
      DCL WRKSPS2(2) BIN FIXED (31) ALIGNED STATIC EXT;
      DCL WRKSPS3(2) BIN FIXED (31) ALIGNED STATIC EXT;
      DCL WRKSPS4(2) BIN FIXED (31) ALIGNED STATIC EXT;


      /* LOCAL VARIABLES */

      DCL EOF BIN FIXED (31) STATIC EXT INIT (0);
      DCL TB BIN FIXED (31) STATIC INITIAL (0);
      DCL TC BIN FIXED (31) STATIC;
      DCL TD BIN FIXED (15) STATIC INITIAL (0);
      DCL TEMP BIN FIXED (31) STATIC INITIAL (0);
      DCL I BIN FIXED STATIC;
      DCL J BIN FIXED STATIC INITIAL (1);
      DCL K BIN FIXED STATIC;
      DCL TEXT CHAR(80) STATIC INITIAL ('');
      DECLARE CMPCD BIN FIXED (31);
      DECLARE TIME BIN FIXED (31);
      DECLARE LCLSCK(2) BIN FIXED (31);
      DECLARE FGNSCK(2) BIN FIXED (31);
      DECLARE WS(2) BIN FIXED (31);
      DCL BFR(0:50) BIN FIXED (31);
      DCL RSPONSE(0:50) BIN FIXED (31);
      DECLARE LEN BIN FIXED (31);
      DCL STRCT CHAR (75) STATIC EXT;


      IF TRACE = 1 THEN
      PUT SKIP LIST('@OPEN:',CMPCD,TIME,LCLSCK,FGNSCK,WS);
      CMPCD = 0;
      RETURN;


@CLOSE: ENTRY(CMPCD,TIME);
      IF TRACE = 1 THEN
      PUT SKIP LIST('@CLOSE:',CMPCD,TIME);
      CMPCD = 0;
      RETURN;


@READ: ENTRY(CMPCD,RSPONSE,LEN,TIME);
      RSPONSE(0) = TB*(256**3);
      IF LEN = 8 THEN RETURN;
      RSPONSE(0) = TEMP;
      IF LEN = 32 THEN RETURN;
      RSPONSE(0) = 0;
      IF LEN ¬=0 & TB = 5 THEN
      DO;
      IF EOF = 1 THEN GO TO SIGNAL;
      ON ENDFILE (SYSIN) EOF = 1;
```

```
      GET EDIT (TEXT) (A(80));
      IF EOF = 1 THEN GO TO SIGNAL;
      K = (LEN/32);
      DO I = 0 TO K-1;
      RSPONSE(I) = UNSPEC(SUBSTR(TEXT,(4*I)+1,4));
      END;
      END;
      IF TRACE = 1 THEN
      PUT SKIP EDIT('@READ:',CMPCD,RSPONSE,LEN,TIME)
      (A,X(1),F(2),51(X(1),B(32)),X(1),F(5),X(1),F(5));
      CMPCD = 0;
      RETURN;
SIGNAL:
      CMPCD = 20;
      WRKSPS1(2) = 80;
      RETURN;


@WRITE: ENTRY(CMPCD,BFR,LEN,TIME);
      TB = BFR(0)/(256**3);
      TC = (BFR(0)-TB*(256**3))/256;
      TEMP = 0;
      IF TB >= 2 & TB <= 6 THEN
      DO;
      IF TC = 8256 | TC = 8192 THEN TEMP = BFR(1)/256;
      ELSE TEMP = BFR(10);
      IF TC = 8256 THEN
      DO;
      CALL POINT(STRCT,ADDR(BFR(1)));
      PUT SKIP LIST(STRCT);
      CMPCD = 0;
      RETURN;
      END;
      END;
      IF TD ¬= 3 THEN TD = TB;
      ELSE
      DO;
      TB = TD;
      TD = 0;
      END;
      IF TRACE = 1 THEN
      PUT SKIP EDIT('@WRITE:',CMPCD,BFR,LEN,TIME,TB,TC,TEMP)
      (A,X(1),F(2),51(X(1),B(32)),5(X(1),F(5)));
      CMPCD = 0;
      RETURN;


POINT: PROCEDURE(I,J);
      DCL (I,J) POINTER;
      I = J;
      END POINT;
      END @OPEN;
```

Appendix D

EXAMPLE COMPILATION
(Diagnostic File)

0 K (, B , , 2) : (K .EQ. 2 : F (4)) ;

ISN	INSTRCT	OPCD	OPRND	SYMBOL
0	2 2 4 1	SICP		
1	5 0 0 0	NULL		
2	1 1	IC	1	
3	5 0 0 0	NULL		
4	1 2	IC	2	
5	2 2 5 0	INS		
6	3 10	AD	10	
7	2 2 2 1	BF		
8	0 0	LD	0	K
9	2 2 0 0	STO		
10	3 24	AD	24	
11	2 2 2 1	BF		
12	6 0	EOT	0	
13	2 2 4 0	SCIP		
14	0 0	LD	0	K
15	1 2	IC	2	
16	2 2 3 0	CEQ		
17	3 22	AD	22	
18	2 2 2 0	BT		
19	1 4	IC	4	
20	2 1 2 0	LUL		
21	2 2 2 2	BU		
22	6 1	EOT	1	
23	7 0	EOR	0	

1 L (, B , , 1) , J (, B , , 5) : (L .EQ. 0 : F (3)) ;

ISN	INSTRCT	OPCD	OPRND	SYMBOL
24	2 2 4 1	SICP		
25	5 0 0 0	NULL		
26	1 1	IC	1	
27	5 0 0 0	NULL		
28	1 1	IC	1	
29	2 2 5 0	INS		
30	3 34	AD	34	
31	2 2 2 1	BF		
32	0 1	LD	1	L
33	2 2 0 0	STO		
34	3 60	AD	60	
35	2 2 2 1	BF		
36	6 0	EOT	0	
37	5 0 0 0	NULL		
38	1 1	IC	1	
39	5 0 0 0	NULL		
40	1 5	IC	5	
41	2 2 5 0	INS		

```
 42     3     46     AD       46
 43     2 2 2 1      BF
 44     0      2     LD        2   J
 45     2 2 0 0      STO
 46     3     60     AD       60
 47     2 2 2 1      BF
 48     6      1     EOT       1
 49     2 2 4 0      SCIP
 50     0      1     LD        1   L
 51     1      0     IC        0
 52     2 2 3 0      CEQ
 53     3     58     AD       58
 54     2 2 2 0      BT
 55     1      3     IC        3
 56     2 1 2 0      LUL
 57     2 2 2 2      BU
 58     6      2     EOT       2
 59     7      1     EOR       1
```

```
2 : ( J , E , E " " , 1 : U ( 0 ) ) ;
```

```
ISN    INSTRCT      OPCD  OPRND  SYMBOL
 60     2 2 4 1      SICP
 61     2 2 4 0      SCIP
 62     0      2     LD        2   J
 63     1      4     IC        4
 64     0      3     LD        3
 65     1      1     IC        1
 66     2 2 6 0      OUT
 67     1      0     IC        0
 68     2 1 2 0      LUL
 69     2 2 2 2      BU
 70     3     74     AD       74
 71     2 2 2 1      BF
 72     6      0     EOT       0
 73     7      2     EOR       2
```

```
3 CHAR ( , E , , 1 ) : ( J , E , CHAR , 1 : U ( 0 ) ) ;
```

```
ISN    INSTRCT      OPCD  OPRND  SYMBOL
 74     2 2 4 1      SICP
 75     5 0 0 0      NULL
 76     1      4     IC        4
 77     5 0 0 0      NULL
 78     1      1     IC        1
 79     2 2 5 0      INS
 80     3     84     AD       84
 81     2 2 2 1      BF
 82     0      4     LD        4   CHAR
 83     2 2 0 0      STO
```

```
 84     3   100     AD      100
 85     2  2  2  1  BF
 86     6       0   EOT       0
 87     2  2  4  0  SCIP
 88     0       2   LD        2   J
 89     1       4   IC        4
 90     0       4   LD        4   CHAR
 91     1       1   IC        1
 92     2  2  6  0  OUT
 93     1       0   IC        0
 94     2  1  2  0  LUL
 95     2  2  2  2  BU
 96     3   100     AD      100
 97     2  2  2  1  BF
 98     6       1   EOT       1
 99     7       3   EOR       3

4 LJ ( , B , , 6 ) , CHRS ( LJ , E , , 1 ) : ( , E , CHRS , L ( CHRS ) :
  U ( 0 ) ) ;

 ISN     INSTRCT    OPCD  OPRND  SYMBOL
 100    2  2  4  1  SICP
 101    5  0  0  0  NULL
 102    1        1  IC        1
 103    5  0  0  0  NULL
 104    1        6  IC        6
 105    2  2  5  0  INS
 106    3    110    AD      110
 107    2  2  2  1  BF
 108    0        5  LD        5   LJ
 109    2  2  0  0  STO
 110    3    139    AD      139
 111    2  2  2  1  BF
 112    6        0  EOT       0
 113    0        5  LD        5   LJ
 114    1        4  IC        4
 115    5  0  0  0  NULL
 116    1        1  IC        1
 117    2  2  5  0  INS
 118    3    122    AD      122
 119    2  2  2  1  BF
 120    0        6  LD        6   CHRS
 121    2  2  0  0  STO
 122    3    139    AD      139
 123    2  2  2  1  BF
 124    6        1  EOT       1
 125    2  2  4  0  SCIP
 126    5  0  0  0  NULL
 127    1        4  IC        4
 128    0        6  LD        6   CHRS
```

```
129     0       6     LD        6   CHRS
130     2  1  1  1    LIL
131     2  2  6  0    OUT
132     1        0    IC        0
133     2  1  2  0    LUL
134     2  2  2  2    BU
135     3      139    AD      139
136     2  2  2  1    BF
137     6        2    EOT       2
138     7        4    EOR       4
* END OF FORM */

***** LABEL TABLE ******

NTRY      LABEL    OFFSET

   0         0        0
   1         1        0
   2         2        0
   3         3        0
   4         4        0

***** IDENTIFIER TABLE ******

NTRY                  IDENTIFIER

  0                      K
  1                      L
  2                      J
  4                      CHAR
  5                      LJ
  6                      CHRS

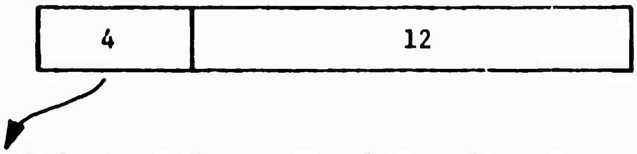
*****     LITERAL TABLE     ******

NTRY TYPE LENGTH OFFSET  LITERAL

   3   E      8      0  01000000
OMPILATION TERMINATED
```

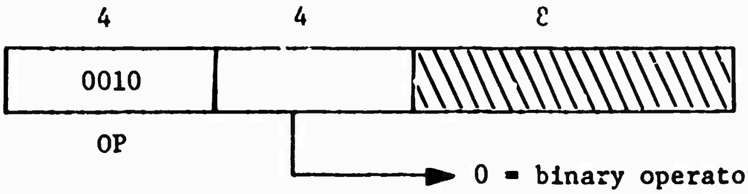
Appendix E

OBJECT LANGUAGE INSTRUCTION FORMATS



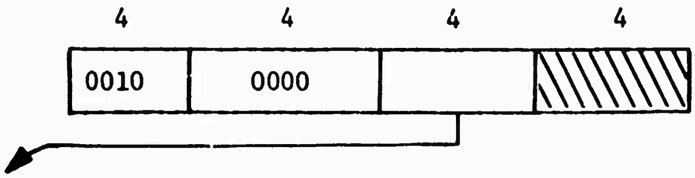
LD = 0 literal or identifier reference
IC = 1 12-bit 2's complement integer constant
OP = 2 operator
AD = 3 address (12-bit positive integer)
ARB = 4 indefinite replication factor
NULL = 5 missing attribute of term

Basic Instruction Format



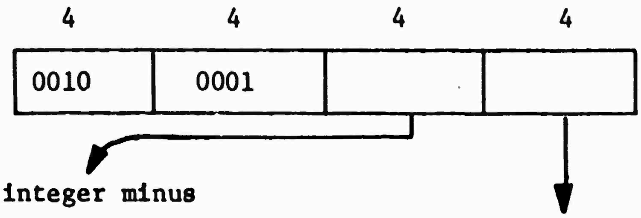
0 = binary operator
1 = unary operator
2 = special operator

Operator Format



0 = integer +
1 = integer -
2 = integer x
3 = integer ÷ (or /), no remainder
4 = concatenate

Binary Operator Encoding



0 = integer minus

1 = load identifier

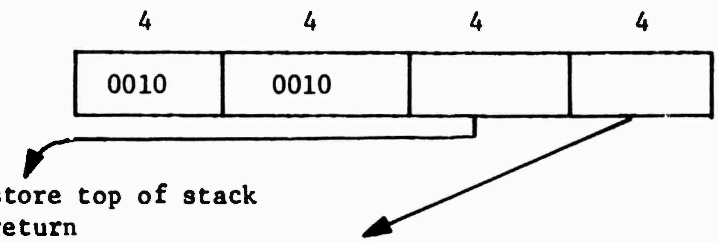
0 = evaluated contents (after dec → binary conversion)

1 = length field

2 = type field

2 = Label Table Reference

Unary Operator Encoding



0 = store top of stack
1 = return
2 = branch — 0 = true, 1 = false, 2 = unconditional

3 = compare — 0 = .EQ. 2 = .LE. 4 = .GE.
1 = .NE. 3 = .LT. 5 = .GT.

4 = move input ptr — 0 = store current into initial
1 = store initial into current

5 = input call — 0 = no store
1 = store

6 = output call

Special Operators Encoding

Appendix F

FLOWCHARTS OF COMPILER

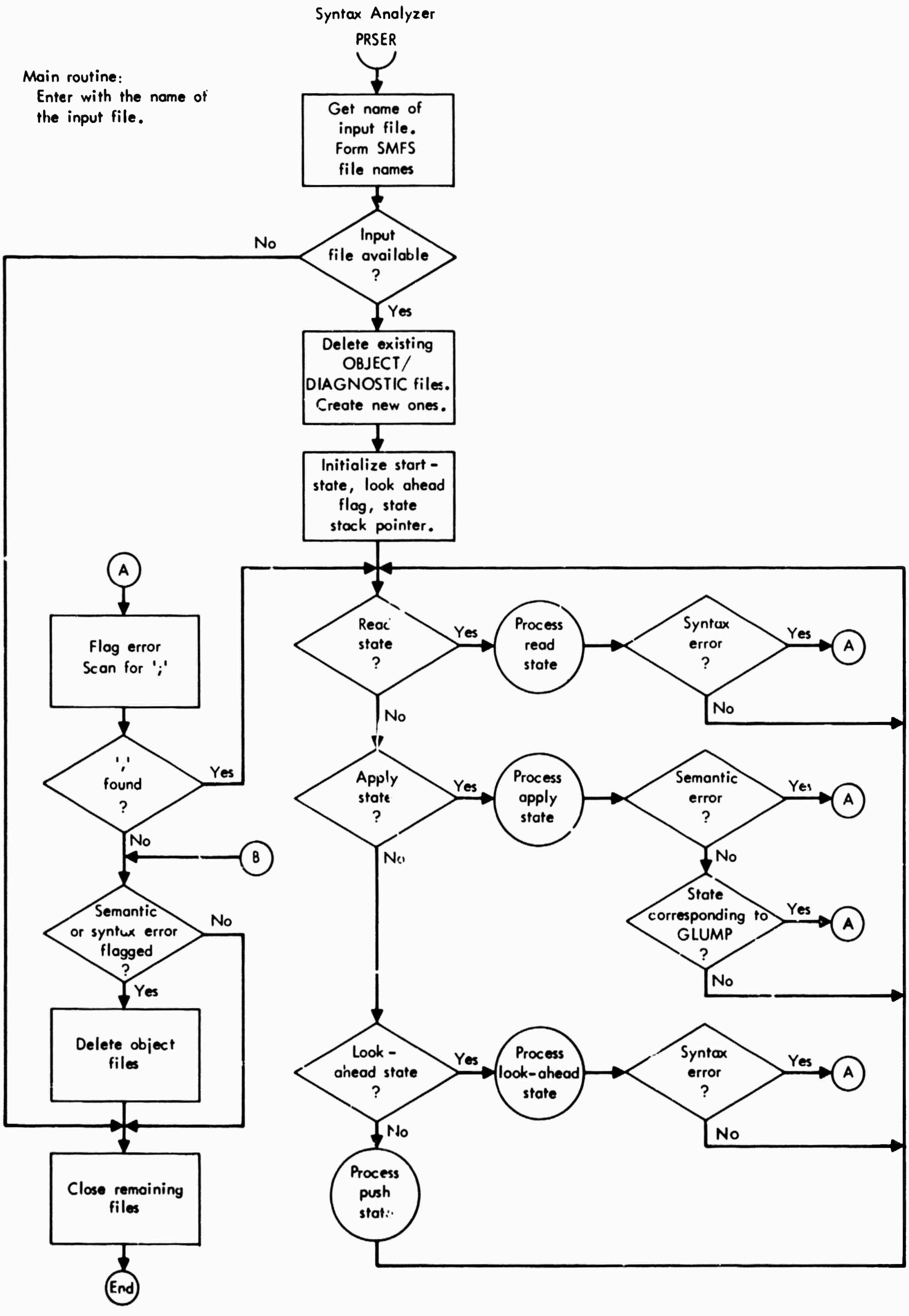


Fig. 10--Syntax Analysis Routine: Control Loop

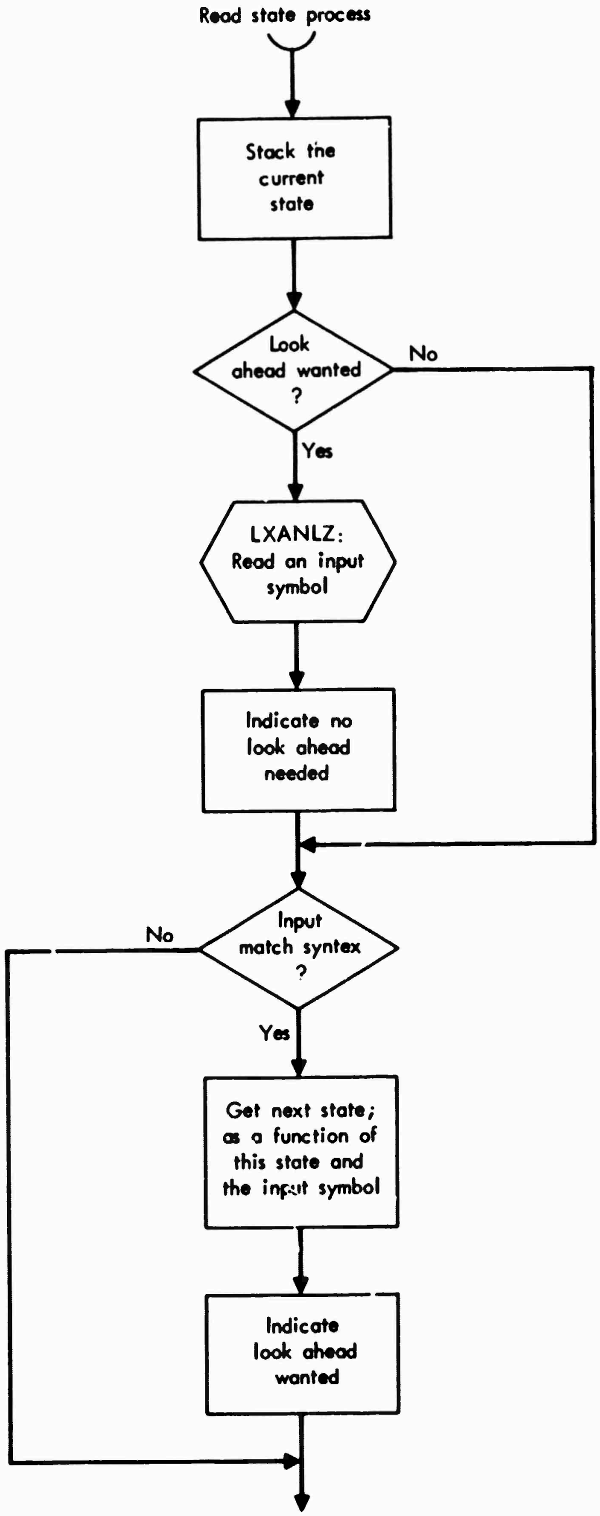


Fig. 11--Syntax Analysis Routine: Processing the Read State

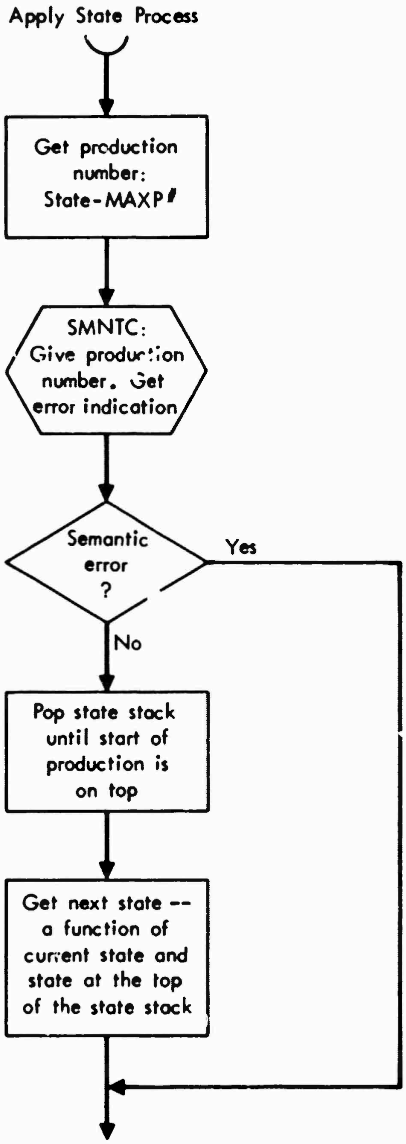


Fig. 12--Syntax Analysis Routine: Processing the Apply State

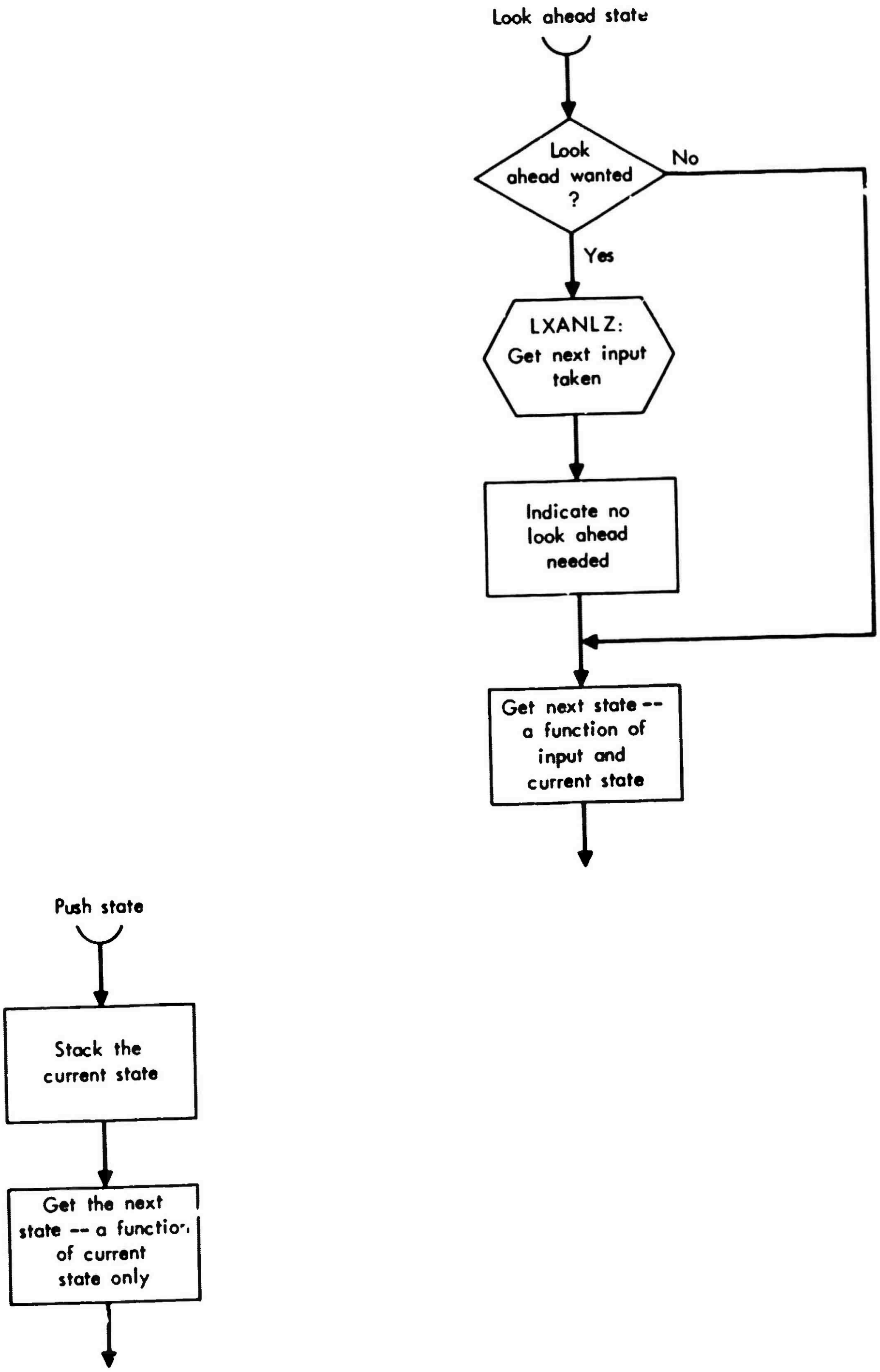


Fig. 13--Syntax Analysis Routine: Processing the Look-Ahead and Push States

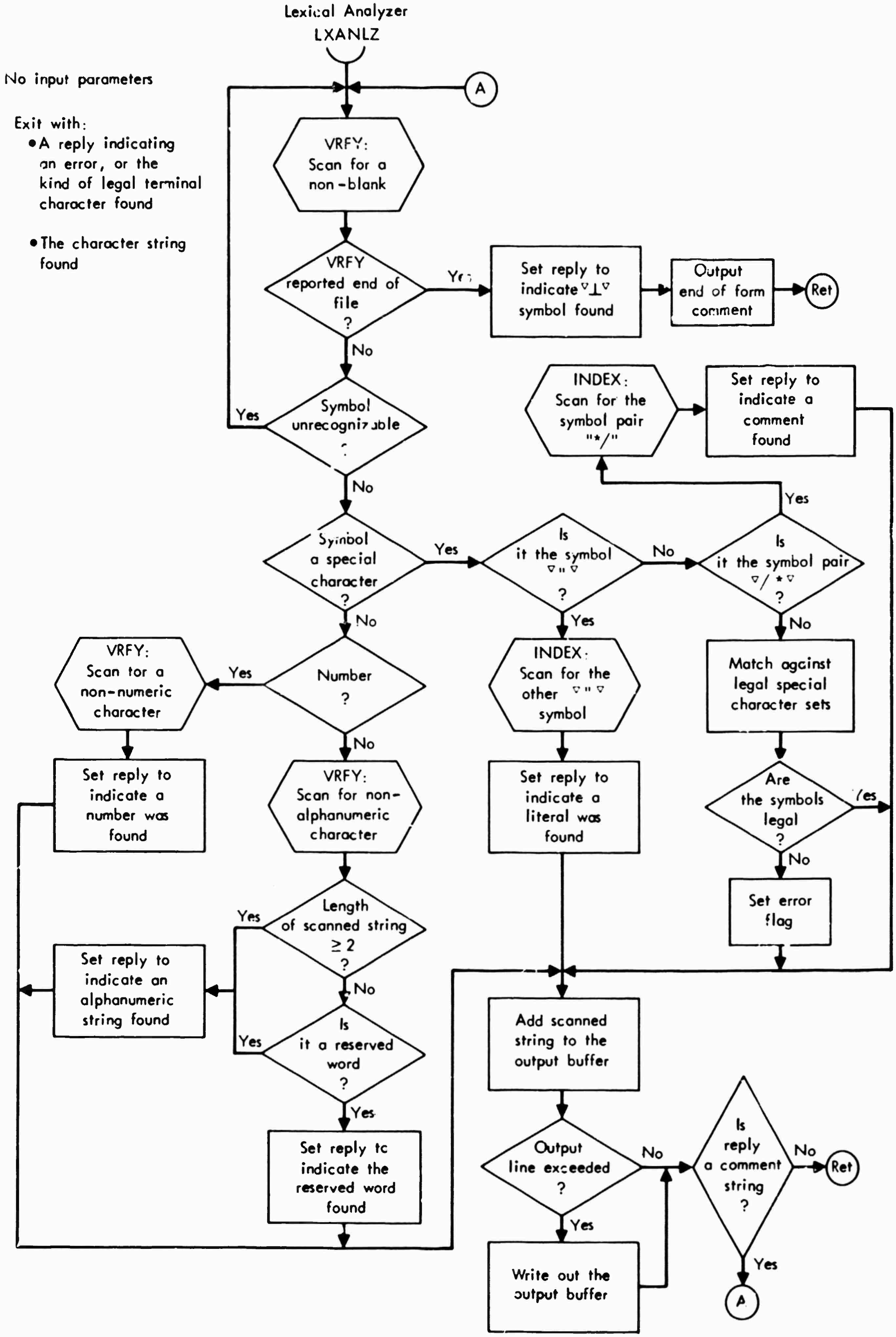


Fig. 14--Lexical Analysis Routine

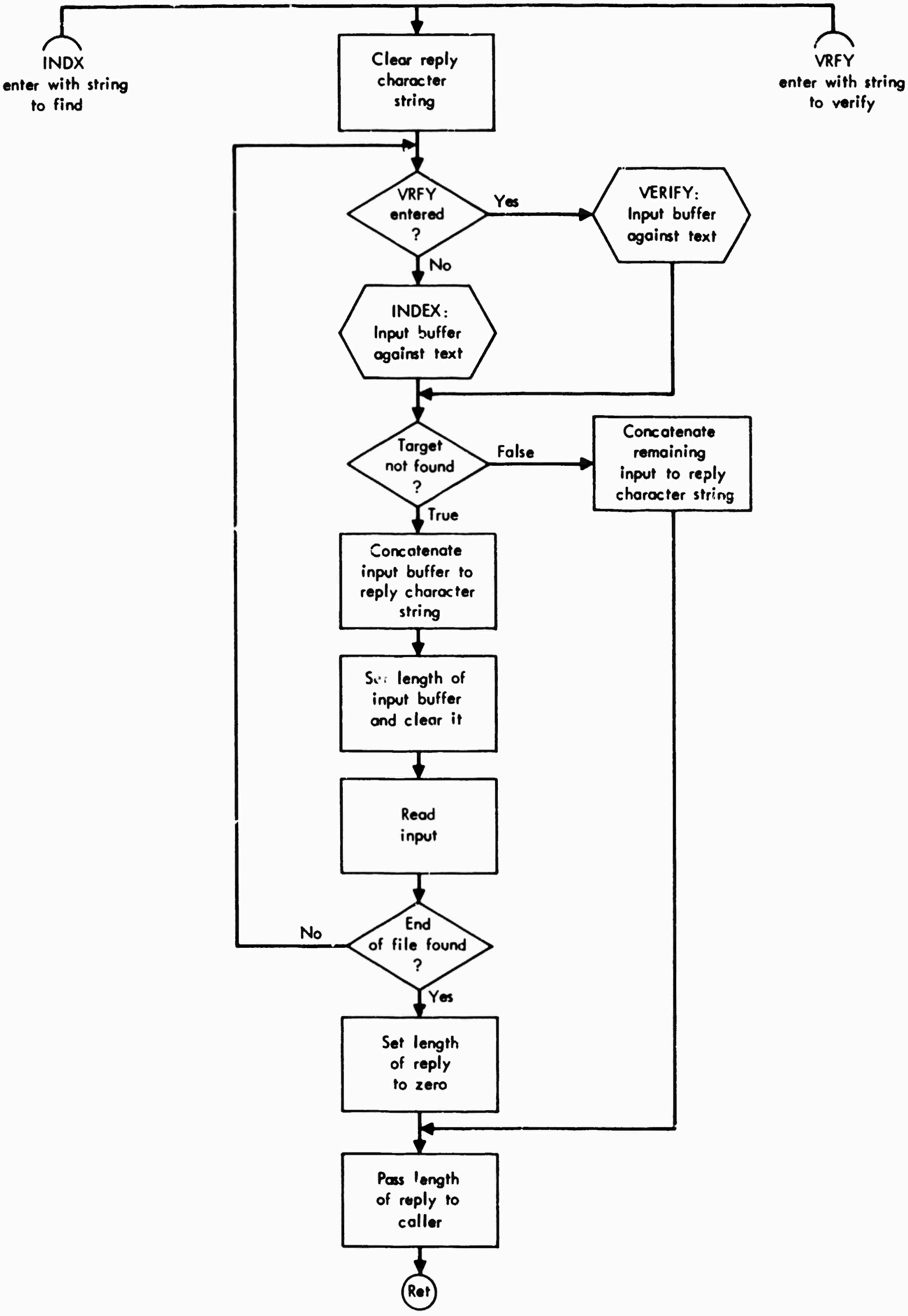


Fig. 15--Lexical Analysis Routine: Verify and Index Subroutines

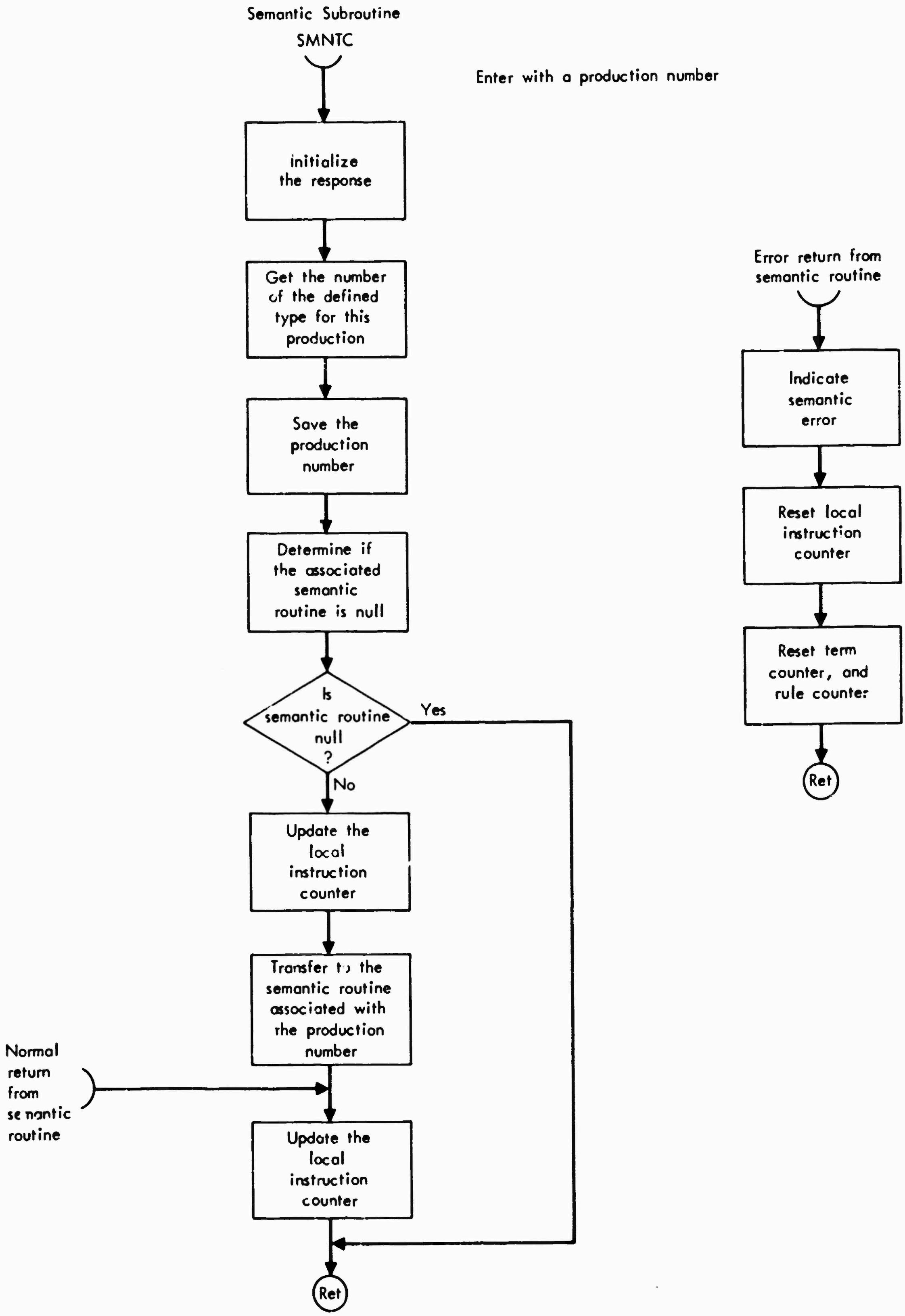


Fig. 16--Semantic Routine: Control Loop

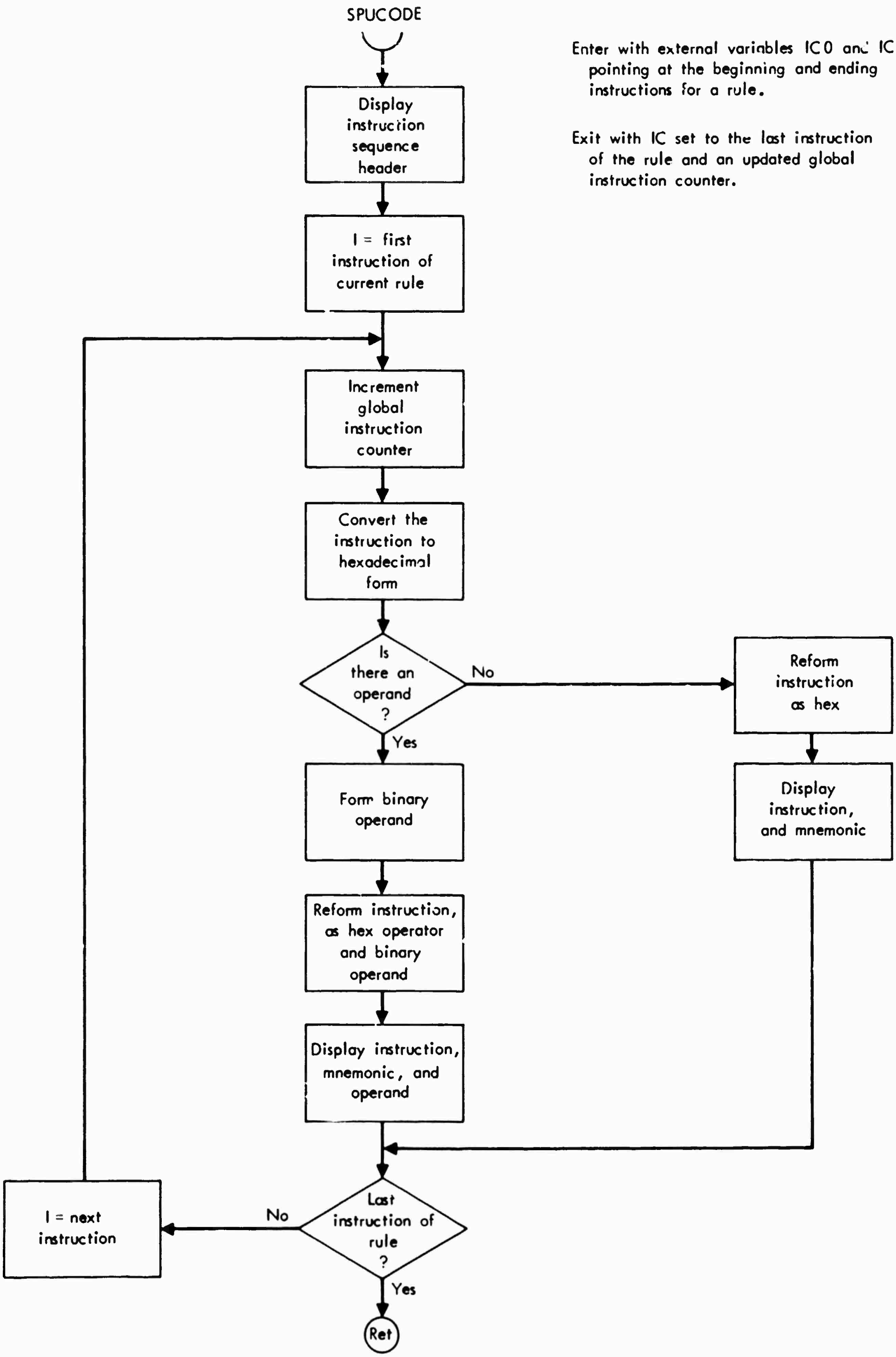


Fig. 17--Semantic Routine: Printing the Instruction Lists

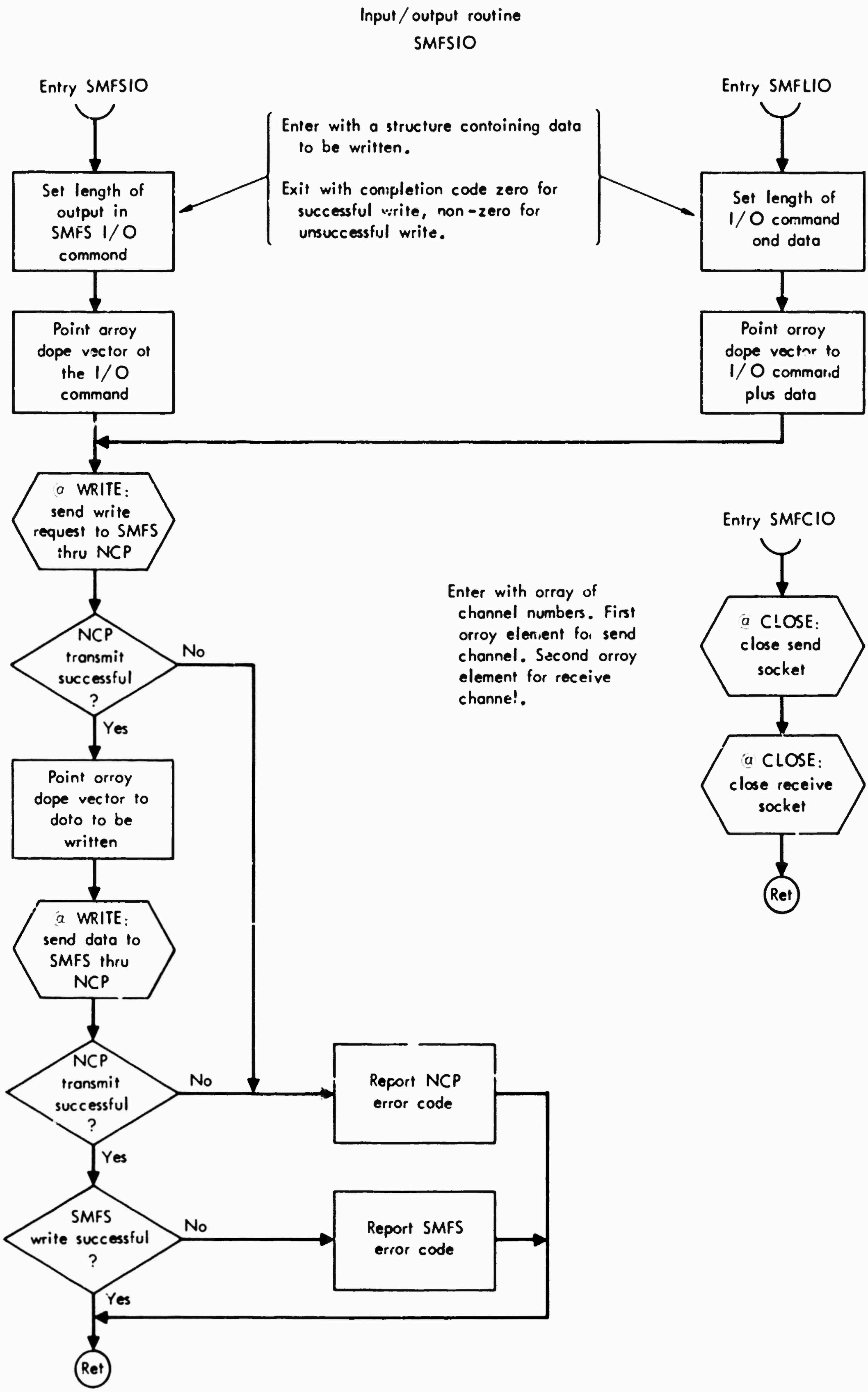


Fig. 18--Input/Output Routine: Executing SMFS Channel Commands and Closing SMFS Files

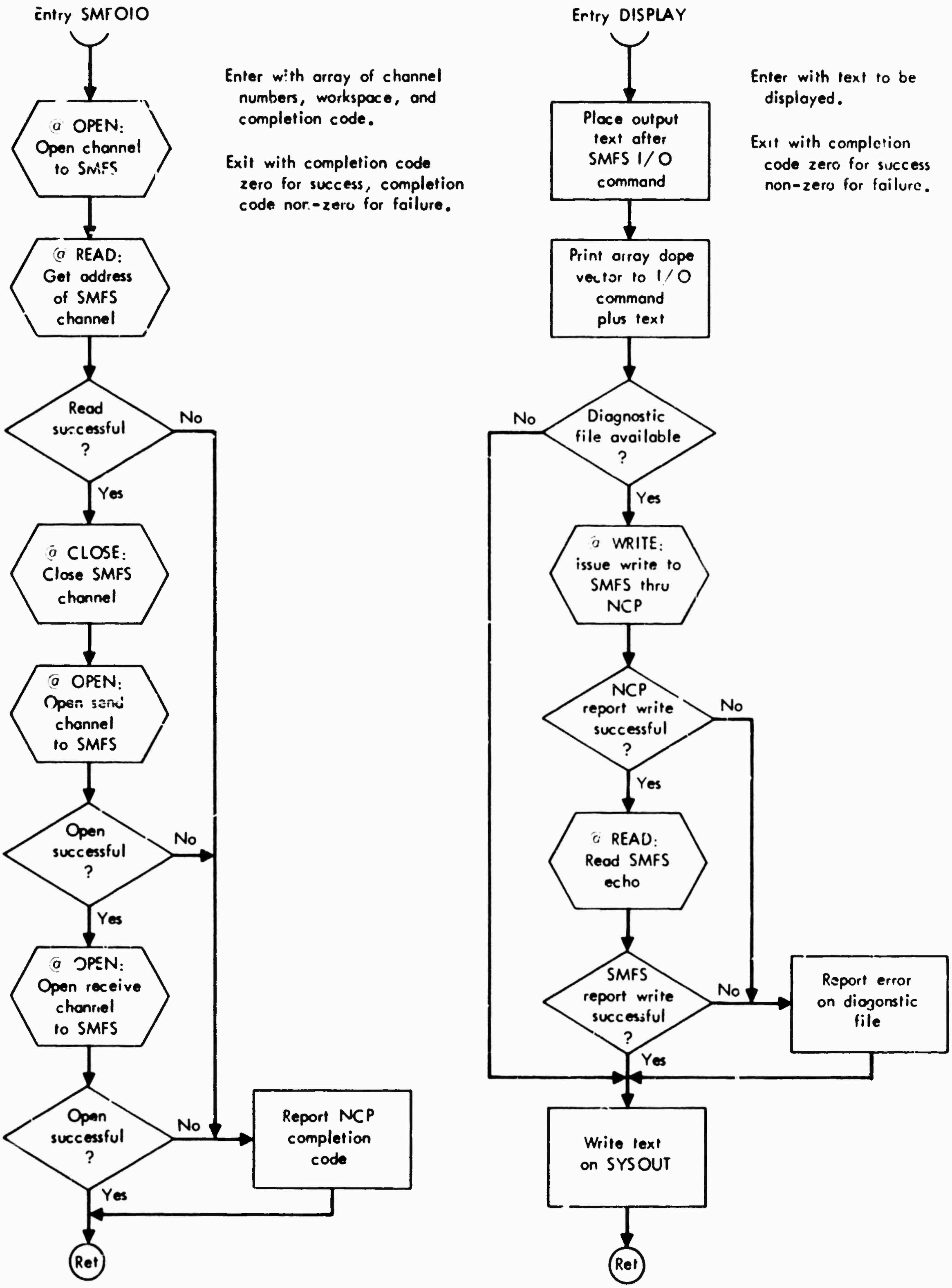
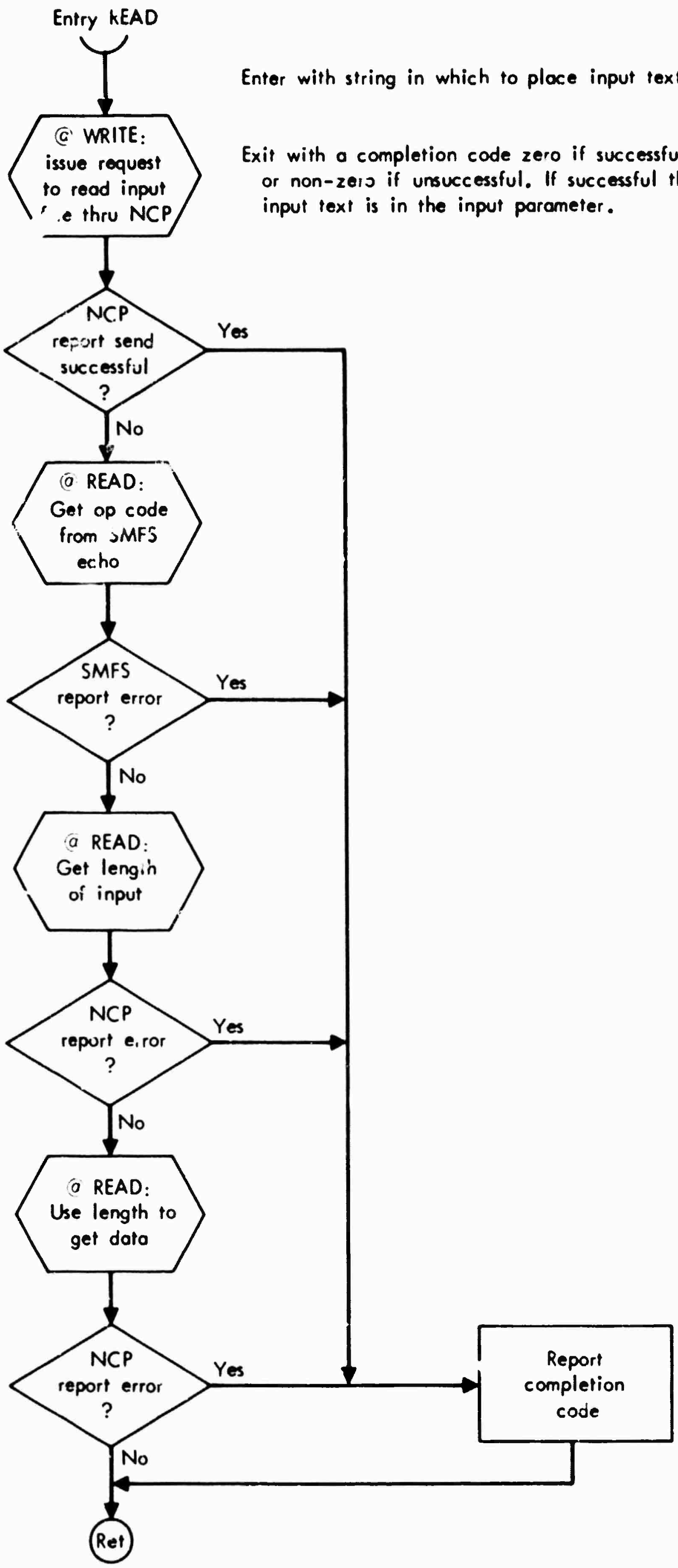


Fig. 19--Input/Output Routine: Opening and Writing an SMFS File



Enter with string in which to place input text.

Exit with a completion code zero if successful, or non-zero if unsuccessful. If successful the input text is in the input parameter.

Fig. 20--Input/Output Routine: Reading an SMFS File

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